ENGINEERING WORK IN PUBLIC BUILDINGS

R. OWEN ALLSOP

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IN

PUBLIC BUILDINGS

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ENGINEERING WORK

IN

PUBLIC BUILDINGS

POWER, LIGHTING, HEATING, VENTILATION, WATER SUPPLY

A Reference Book for all engaged in the Design and Construction of Asylums, Hospitals, Colleges, Hotels and other large Institutions

BY

R. OWEN ALLSOP

ARCHITECT

AUTHOR OF "PUBLIC BATHS AND WASH-HOUSES," ETC., ETC.

SEVENTY-FIVE ILLUSTRATIONS

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PREFACE

THE present work, dealing primarily with the problems involved in Institutional Engineering, originally appeared in the form of a series of articles in *Surveying and the Civil Engineer*, and is now republished by kind permission of the *Pall Mall Press*. The whole, carefully revised and enlarged, comprises a collection of essays on such matters as will be in the mind of the architect or engineer concerned with power, heating, lighting, ventilating and water supply in hospitals, asylums and the like communal buildings.

I here gratefully acknowledge the assistance afforded me by the Local Government Board in facilitating my inspection of the engineering departments of existing public institutions.

R. O. A.

37 NORFOLK STREET, STRAND, LONDON:
January 1912.

ENGINEERING WORK IN PUBLIC BUILDINGS

CHAPTER I.

INTRODUCTORY.

The work of the engineer in public buildings and institutions comprises the lay-out and supervision of arrangements for lighting, heating and ventilating. In modern hospitals, asylums and poor-law institutions this represents a considerable plant. Our present proposal is to consider the engineering problems in such public and municipal institutions as represent *habitations*—distinct from town halls, libraries, theatres, etc., where, naturally, the engineering work is of a simple and more everyday character. An exact parallel to the public institution may, however, be found in the private institution—orphanage, home, etc.; and both such classes of building find a close resemblance in the large modern hotel. In any of these latter, we now find a formidable array of engineering plant—powerful boilers, complete lighting sets, wells, and devices for heating and ventilating and water supply. All buildings, therefore, where a large community of persons are housed, present engineering problems generally similar, and varying chiefly in detail. The palatial hotel thus resembles the plain workhouse. It cannot be said that the latter is the simpler of the two, since, as a rule, the compact planning of the hotel, as contrasted with the diffuseness of the public institution, makes for compactness in the engineering arrangements.

In both the private hotel and public institution the first essential in engineering work is centralisation of the plant, since this conduces to economy in first outlay, in working expenses, and in supervision. This centralisation, or compact grouping of important engineering works about a virtual point, is the most marked feature in modern tendencies. Of old, public institutions had coal-burning here and

coal-burning there. The aim of the engineer is now to burn coal at one spot—the boiler furnace—and to distribute heat by the medium solely of water or steam, pending the discovery of an economical method of electrical heating, which, with its simple wires and cables, would be ideal for a rambling assemblage of buildings covering 20 or 30 acres of ground all told. Attention to the principle of orderly grouping and centralisation has frequently reduced annual coal bills by one-third—an important achievement where these bills are estimated only in thousands of pounds.

The four prime considerations in engineering in public institutions and buildings of the same general class are: lighting, heating, ventilation, and water supply. Regarding the whole plant as a machine, upon the economical and efficient working of which the health and comfort of the inmates depend, the question of public institution engineering presents an interesting problem in thermodynamics. This would not be the case if attention were absorbed by the apparently more attractive subject of engines, boilers, and dynamos; and were the heating, ventilating, and water supply regarded as subjects fit only for a kind of aggrandised practical "plumber and hot-water engineer"; or if the whole duty before the plant were roughly estimated, and 50 per cent. added for safety. The interest resides in the fact that in no two buildings do the load curves resemble one another, or the lighting load and coal-consumption curves necessarily co-ordinate. As a result, much thought is required to arrange a suitable system, and instal appliances that will bring about the greatest economy in working when considered with reference to capital expenditure.

As a general rule large modern public institutions generate their own electrical energy and raise water from their own wells. The question for or against auto-generation of electricity determines the main character of the public institution engineering plant. Ordinarily, the engineer dealing with a complete institution engineering plant has to provide both power and heat. Hence, the problem becomes essentially thermodynamic—how to produce the requisite amount of heat energy and mechanical energy with the least possible expenditure in fuel, having regard to efficiency, economy in initial outlay, running costs, repairs, maintenance, and depreciation.

At the outset, therefore, the engineer requires to provide a prime mover. The question immediately presents itself: Of what kind? The mechanical energy required to be developed is relatively small—the lighting, ventilation and lift-driving, laundry machinery and pumping, total a small load when compared with that of a public-supply power-house. Known facts as to the thermal efficiency of small engines, and the tendency of the day, direct one's thoughts to the internal-combustion engine, under these conditions; but further review of all

attendant circumstances shows us that we have, in the very imperfection of the steam-engine cycle, a valuable asset in the heat rejected by the engine exhaust, which far exceeds the waste heat of both jacket and exhaust of the gas or oil engine. Moreover, the simple method of originating caloric by combustion in boiler furnaces, and the use of the natural British source of heat—coal—together with the absolute necessity for *some* steam generation, all indicate the steam engine as the most suitable prime mover for public institution engineering.

We thus arrive at a battery of boilers as the means of producing at once thermal and dynamic energy. The size and number of engines and of boilers are questions of maximum demand for steam and load factor, and economical results may be greatly assisted by intelligent application of the principles of electric energy accumulation—the storage battery. Thus our tentative consideration of the elements of public institution engineering discovers as necessary features: (1) boilers, (2) steam engines, (3) electrical generators, and probably (4) accumulators. The natural phenomena concerned are coal combustion, the origination of heat, steam raising, and the generation of electrical energy. The objects are lighting and warming apartments, etc., and the operation of electric motors for several purposes. The first and last are direct, the intermediate (warming) indirect; and the question here opened up is a somewhat thorny one. The matter of heating water or the use of steam, either live, at reduced pressure, or exhaust, is simple enough, but the subject known generally as "heating and ventilation" is not so—instance the multifarious systems, and the fact that a recent Local Government Board Committee, after inspecting some ninety poor law and other institutions, and examining many engineers and others, state in their Report that the acquisition of further data in connection with this subject is highly desirable.

In all the above considerations we have been only on solid ground, whereon engineers and experts express agreement generally by providing steam boiler and engine in convenient buildings. From out of this power installation comes a valuable by-product—exhaust steam, with its 1000 odd heat units rejected by the engine, but quite useful to the heating engineer. The problem that arises is, How is he practically to employ this heat? The question of amount of heat required per cubic foot of apartment or per square foot of surface is simple, and has been reduced to tables, all more or less concurring. The problem enters when heating *plus* ventilation is considered. Round this subject there still rages (or smoulders in subterranean fashion) a battle royal—"natural" *versus* "mechanical" ventilation. And there is always with us the further debatable point—hot water or steam for heating? These questions, and the further one of position of radiators, and radiators *v.* pipes, radiators hidden or exposed, above or below, are to be faced by the engineer who seeks a satisfactory workable system of keeping the inmates of a

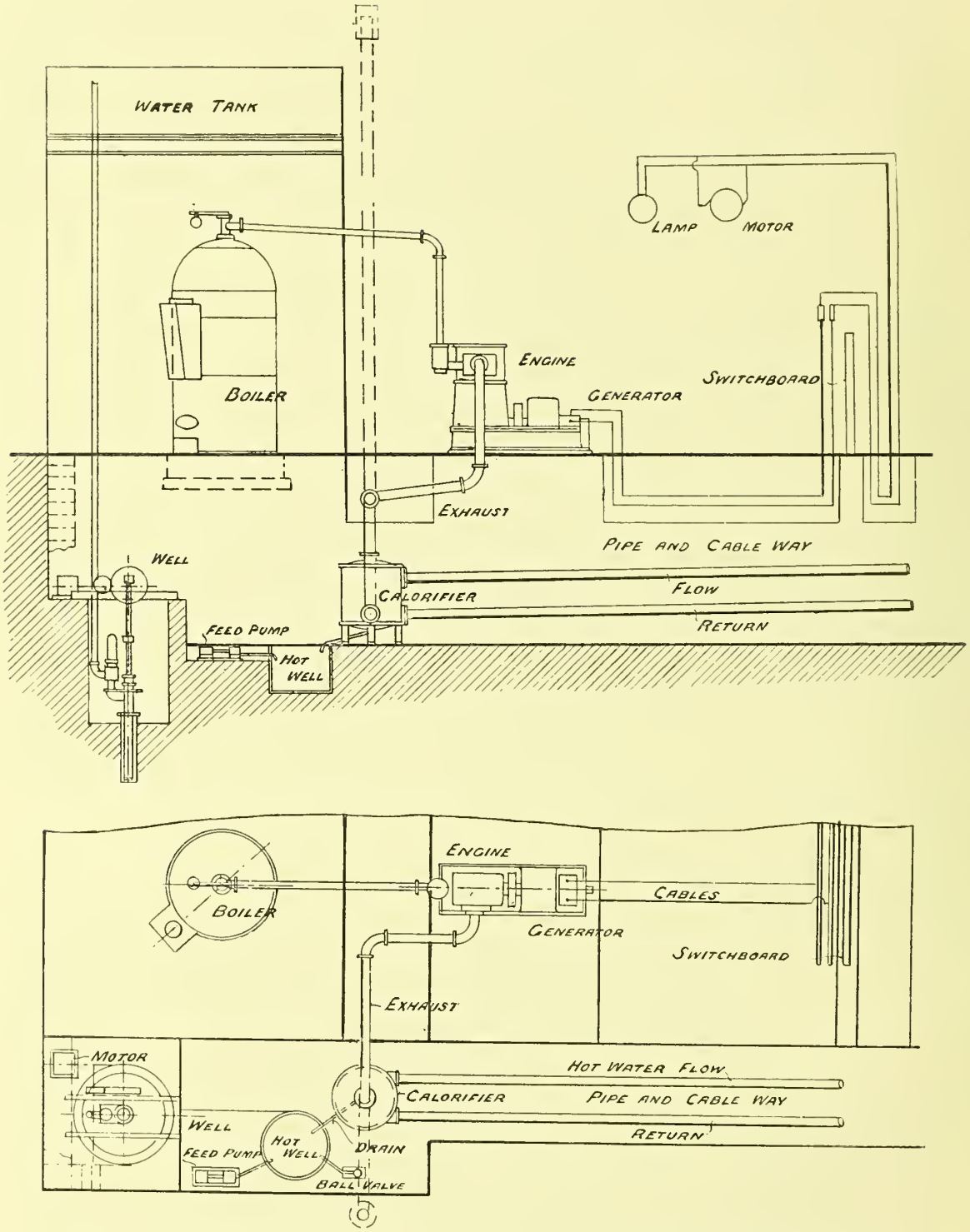


FIG. 1.—HEATING A BUILDING BY EXHAUST STEAM FROM ELECTRIC LIGHTING ENGINE.

hospital, etc., comfortably warm and supplied with a necessary abundance of pure air.

The first impression given by a large engineering installation of this kind is one of considerable complication. The effect is apparent only, and arises principally from the medley of mains, pipes and drains, connections, etc., and the vagaries of the building plan. The elimination of non-essentials, or variables, shows the main principle to be simple. Lay-out schemes should be first studied in diagram without details. This enables a grasp to be obtained of essentials and fundamentals. A system may be reduced to its elements, and so sketched diagrammatically. Thus, Fig. 1—a plan and super-imposed sectional view—shows all the essentials of a system of useful power, light, heat and water supply. It is immaterial whether a small vertical boiler or a number of powerful shell or water-tube boilers are required, since main principles remain constant. In this way, the diagram given, which assumes a low-level calorifier as an essential, may represent the elements of a large installation of plant. There is coal-burning, steam-raising, conversion of steam into electrical energy, and that, again, into conveniently distributable mechanical power and to light, while the main engine exhaust is in part utilised—in the water heater—and the water supply is from a private well. A rough diagram of this kind is better, at first, than extensive planning in detail. Together with a schedule of engineering requirements, the engineer arranging the lay-out can proceed to amplify the plant in his mind's eye, and estimate the various duties and loads, and so arrive at the maximum demand for power, light and heat, and, if he chooses, theorise to three places of decimal.

First, principles and systems; then up-to-date details, which must necessarily be largely represented by the proved inventions of manufacturers.

Obviously, what the engineer requires of the promoters of the institution is a schedule of requirements—the number of lights, space to heat, etc. Furnished with this, and the architect's provisional plan, he can make a tentative lay-out.

CHAPTER II.

THE LAY-OUT OF AN ENGINEER'S DEPARTMENT IN PUBLIC INSTITUTIONS.

The accepted medium for power, light and heat being steam at pressure, the steam boiler is the first consideration in "institutional" engineering. The type of boiler best suited for public institutions varies with the purposes of the building, and as to whether or not electrical generation is to be carried out. The vertical, shell and water-tube boilers are severally employed, while on certain occasions the loco. and the dry-back types are adopted. In most poor-law institutions the shell boiler, either plain Cornish or Lancashire, or with Galloway tubes, is to be found, and the reason commonly assigned for this preference is that such may be looked after by unskilled inmate stokers. The growth and size of the modern institution, however, and improved personnel in the engineers' quarters, leave no manner of valid objection to the employment, in suitable cases, of powerful, up-to-date water-tube boilers.

Inasmuch as building-heating represents a large part of the whole duty of a battery of boilers in a habitated public building, at least one-half of the whole boiler equipment will be out of commission during, say, five months of the year, which period affords the engineer an opportunity for repairs. The question of furnaces—hand versus automatic stoking—is one that depends largely on the nature of the establishment. The great advantage of the mechanical stoker is that it enables cheap fuel to be burned smokelessly, or practically so. The employment of small bituminous as against hard steam coal may lead to very great economies, shown in the annual fuel expenditure accounts; but it has been demonstrated in practice that the installation of automatic stokers does not necessarily lend itself to reduction in the number of human stokers.

It has been shown that, where the load greatly varies, hand-stoking may possess advantages. Nevertheless, the installation of automatic stokers in large modern public buildings may be reasonable, and is an early question for those having the charge of engineering schemes to consider. The pros and cons centre around the matter of first cost; and whether competent hand-stokers have to be paid, or whether (as in poor-law institutions) inmate labour is to be largely

employed. It must be remarked in passing that some criticism may be reasonably directed against a practice of putting incompetent men to attend high-pressure boilers. It may be, and seems right in a workhouse to give occupation to able-bodied, or sufficiently able-bodied, inmates; but, apart from questions of safety, economy and efficiency, the practice may evidently lead to abuses.

In view of the rambling, widespread nature of many country institutions, the position of a boiler-house requires, in planning, the first consideration of the

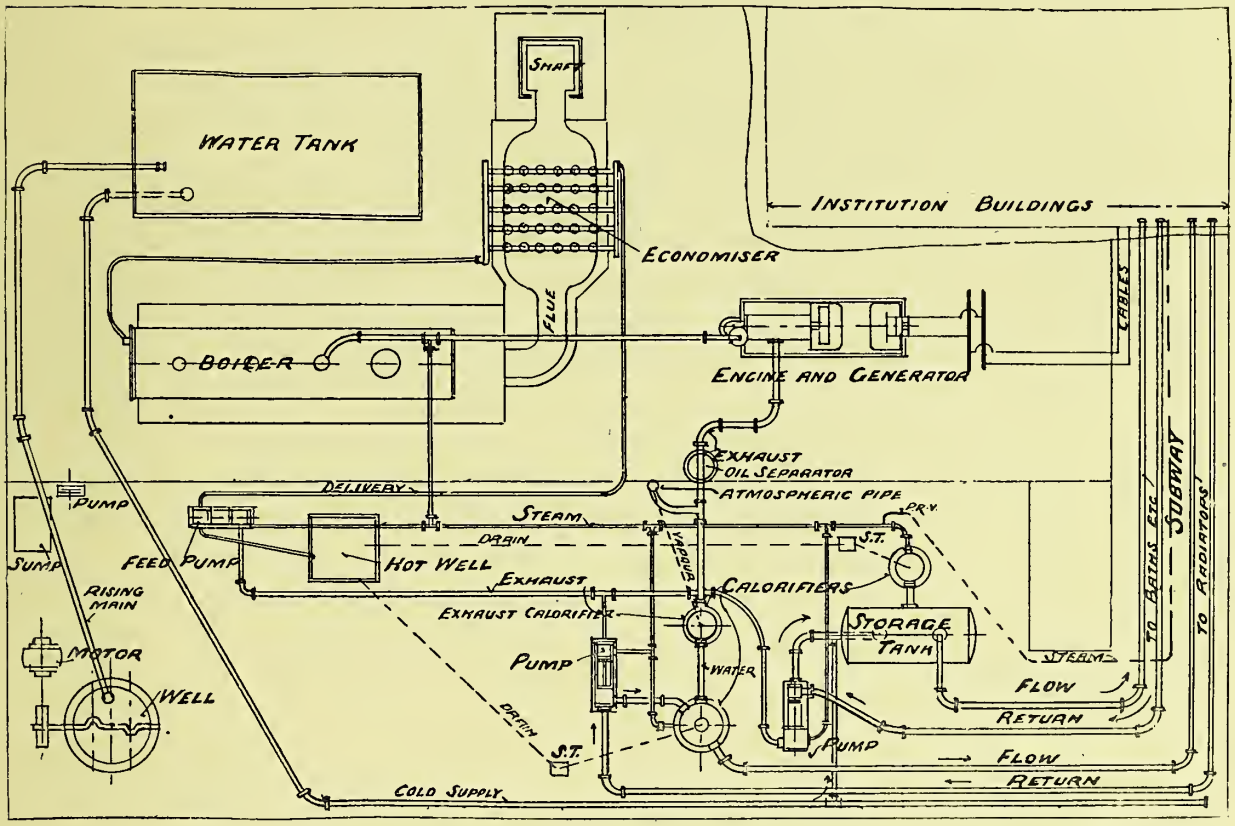


FIG. 2.—DIAGRAM OF ENGINEERING WORK IN A PUBLIC INSTITUTION: PLAN.

Live steam and auxiliary exhaust calorifier for building-heating; live steam calorifier for baths, etc.

engineer, or engineer and architect acting conjointly. The position of the boiler-house is, in a measure, a key to the general plan. It is evidently desirable to group round the boilers the remainder, as far as possible, of the engineer's department. Hence, frequently the boilers are controlling factors in any scheme of institution planning, particularly in the country; the case thus differing from, say, public bath-houses, where the swimming-baths, by their enormous area,

relative to other parts of the building, completely dominate the main outlines of a plan. The principle, therefore, is to group round the boilers the engine-house, wells, heaters, calorifiers, etc. Again, it is desirable to bring the laundry—always a most important department in asylums, hospitals, homes and similar institutions—as close as conveniently possible to the boiler-house; and further, some advantage accrues in bringing up, compactly, the kitchens. The latter may not be convenient for the best working of the establishment; the laundry stands on a different footing, and, apart from proximity to steam supply, and to the engineers, can be conveniently located at practically any point.

The centralisation, grouping and compacting of the engineer's department facilitate the attainment of the great aim—coal-burning at one spot. It also simplifies supervision. In city buildings, boilers and engineers' department are almost invariably located below ground-level—not an ideal arrangement, but necessary on economic grounds in expensive sites. A trouble here sometimes occurs in getting straightforward drainage of the blow-off, and will call for ingenuity in planning. A low level for boilers and calorifiers has a practical advantage where natural thermo-syphonage or gravity circulation of heating water through mains is required; but of late years a system of positive pumping by centrifugal or other pumps or by steam injector action has been increasingly in favour, so that the point is not so vital as it was at one time considered. Nevertheless, on an undulating country site, it is good and natural to place the heaters at a low level relatively to the ground floors of the establishment buildings. The plan conduces to a practical arrangement of heating mains. Further, inasmuch as the high ground, on country sites, for a large communal establishment, is preferably selected as the most pleasant and healthful for residence, the principle of placing boilers at a low level works in harmoniously with any general scheme embracing up-to-date ideas.

In much-cut-up institutions the engineering department should form, practically, an isolated block, the real connection to residential, service and official blocks being by means of cable-ways, pipe-subways and conduits—the means of lighting, heating, and water supply. This enables ample space, vertically and horizontally, to be allocated to the engineers. A feature of city establishments is the injurious cramping of space—unavoidable, certainly, in the circumstances, but none the less objectionable, and the cause of loss of efficiency and inconvenient working. Cramped head-room, as in boiler-houses, is a false economy. It leads to expense in details of lay-out, and inconvenient working and supervision. Examples of weird engineering are to be found, especially in the older class of London public building. A common defect is an insufficiency of head-room over boilers; and, as a rule, in such places an atmosphere uncomfortable for, and injurious to, the occupants.

Where there is ample ground area, as in country institutions, it is not only better practice, but less costly, to spread out horizontally rather than cramp the area and enlarge vertically. By following this principle as fundamental, convenient boiler and engine houses, etc., are insured with ample light and ventilation, and space for workers to operate conveniently and therefore efficiently.

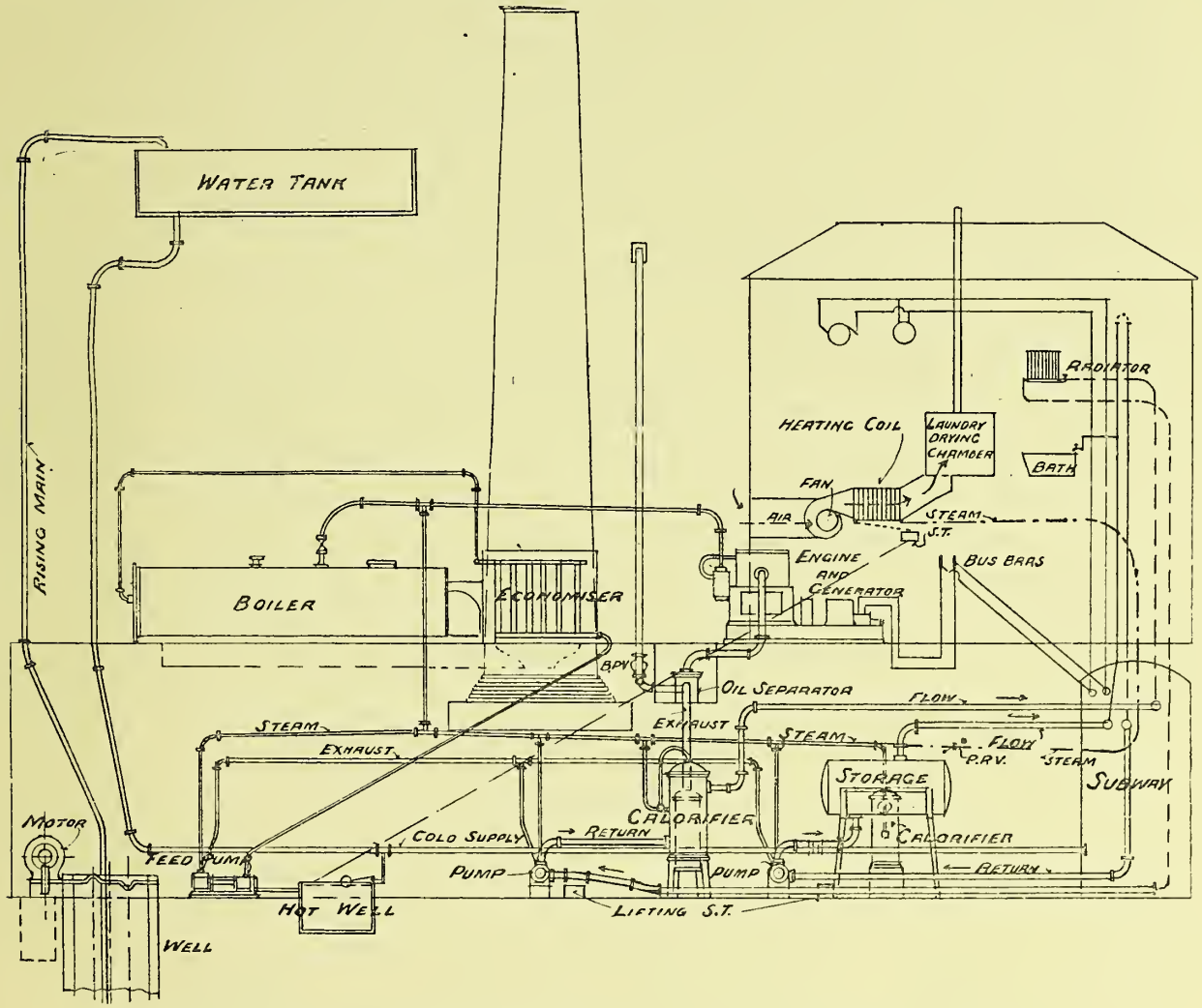


FIG. 3.—DIAGRAM OF ENGINEERING WORK IN A PUBLIC INSTITUTION: SECTION.

Live steam and auxiliary exhaust calorifier for building-heating: live steam calorifier for baths, etc.

As a first consideration, in laying out any building having an extensive boiler equipment, the means of access for coal waggons will be studied—to the end not only that coal may be readily carted in, but that the least possible handling is

required before it finds its way into the boiler furnaces. The ideal arrangement is a shoot direct into bunkers, with conveying gear to hoppers, discharging over automatic furnaces—the modern power-house system ; but in few public institutions is the first cost of this arrangement justified. More often the coal enters by carts, and, after passing over a checking weigh-bridge, is shot into cellars or cellar-like bunkers, or dumped at the same level, being trimmed and shovelled into furnaces. And in this arrangement careful planning will conduce to economy of labour. The act of hand-stoking, comprising the sweep of shovel, its extent and direction, must be kept in mind, otherwise, instead of an operation practically direct from bunker-mouth to furnace, there will be an intermediate one of trimming or coal-heap formation on the boiler-house floor. The medium between excessive and restricted elbow-room must be maintained. Every stoker worth his "salt" will take a pride in a neat, orderly boiler-house. Let him be encouraged by at least competent planning of details.

Assuming the necessity for prime movers, as for electrical generation, a boiler-house cannot be planned without direct reference to an engine-house or generator room. As a general practice the recognised power-house system whereby the two departments have a common, or party, wall is the most straightforward, natural, convenient, and compact ; and it does not bear on this remark that the institution power-house is an insignificant affair when compared with its larger public supply confrère. It can be a model, and is well made so. Under this now almost standardised arrangement, the stoking end (of boiler-house) fronts away from the engine-house, a main flue runs along the party wall, which steam mains pass through, direct to the engines, or turbines ; these latter, in their turn, have, naturally, their steam ends towards the boilers and their generators distant ; while, further off, on the other engine-house side wall, are switch-panels and gear. The general arrangement here described cannot well be improved. We have : (1) coal, (2) furnace, (3) boilers, (4) steam outlet, (5) steam inlet to engine, (6) engine, (7) generator, (8) cables, and (9) switchboard, the whole perfectly natural and applicable to the smallest electrical generating installation as to the largest public supply power station. Only a cramped site and basement engineering department for special building service can excuse the upsetting of this natural arrangement of practical appliances whereby the phenomena of combustion, steam generation, and the conversion of heat energy to electrical energy, and the collection, distribution and control of the resultant "current" are carried out in orderly sequence.

If, therefore, the site of a public building—such, for example, as a country institution—affords ample ground area, the central feature of the engineering department will be represented by a plain block, in the main simple and rectangular, a part of which is devoted to steam-raising and a part to electrical generation.

Straightforward planning is here required, and it should be seen that, instead of the extremely doubtful practice of installing excessive boilers and plant (on the idea of saving by getting the whole more cheaply), the modern practice—of the genuine power-house, again—is followed : space left *at the end* of the boiler and engine-houses, so that an extra unit, either complete—boiler, engine, generator and panel—can be added, or individually, as an extra boiler, on account, say, of increased building-heating duty making this recourse necessary.

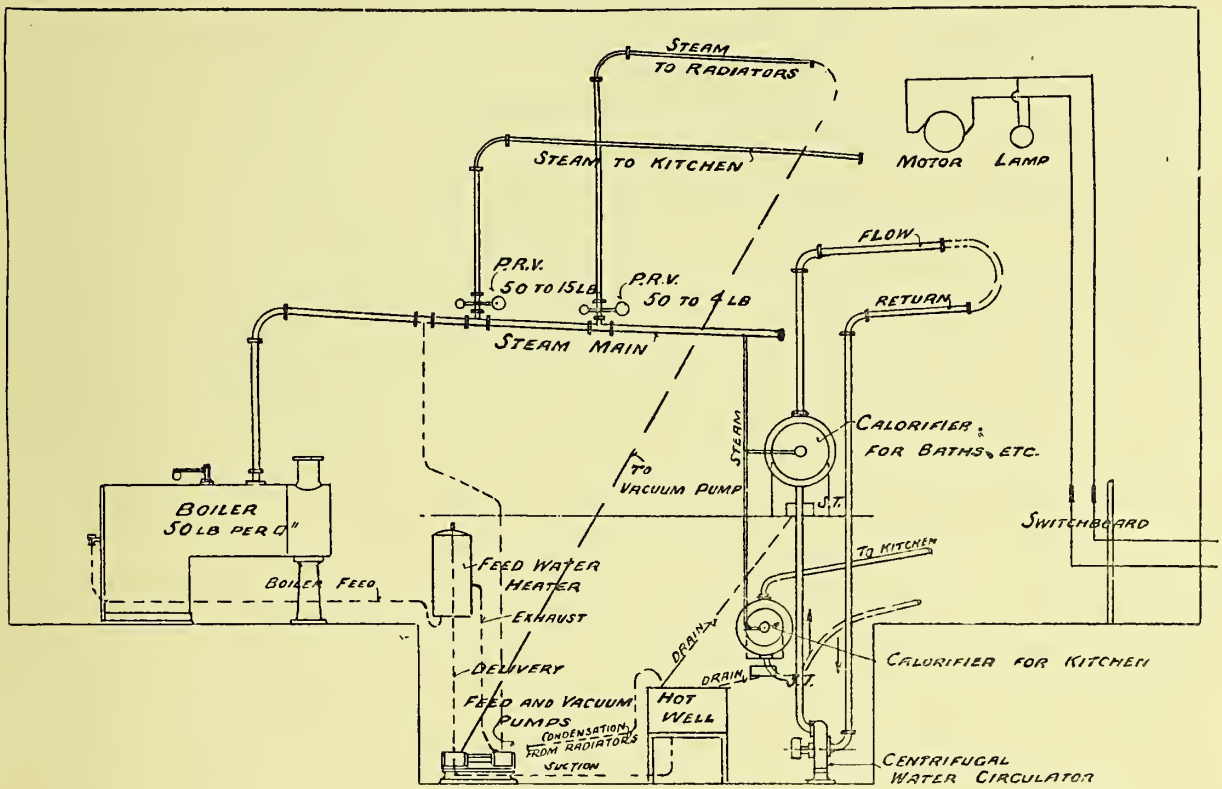


FIG. 4.—DIAGRAM OF HOTEL ENGINEERING. VACUUM STEAM HEATING: SECTION.

Live steam calorifiers for baths and for kitchen supply.

Before dealing with the question of building-heating, as affecting the planning of an engineer's department, for public buildings and institutions, we may here tentatively notice the vital question of water supply. The consumption of water is naturally very heavy in public buildings of the hospital or home variety, the number of inmates being, in large examples, considerable, the whole becoming more like a small town or village as respects its demand for water. There is the general potatory supply, the kitchen supply, and that for laundry, lavatory, sanitary and miscellaneous needs, besides the water required in and for the purposes of the

engineer's department. This may total so large a number of gallons annually that the prices of the public supply authorities and companies—should such indeed be available—become prohibitive, even at 6*d.* the thousand gallons, which is seldom now so low a price. The cost of raising from a private artesian well or wells should not, including all charges, be more than 2*d.* or 3*d.* per thousand. Even if 3*d.*, the cost is one-third of the public charge at 9*d.* per thousand gallons ; so that we find it quite the ordinary and justifiable procedure for large institutions to put down efficient plant for raising water from wells, and the same is now common practice in most or all large modern hotels, in towns where charges so often now rule at a flat rate of 1*s.* per thousand gallons. Assuming, then, that the private system is to be adopted, the first necessity is a capacious storage tank to which the deep-well, triple-barrel or other pumps raise the water from natural standing level, which latter will vary greatly throughout the country and in London is tending to sink. In the provision of such a tank, advantage may frequently be taken of some necessary building as foundation for the walls of the tower, should this not be a purely steel-frame construction. It may require to be an erection of considerable height in some large public institutions on particular sites.

We have generally considered the steam and power arrangement and water supply in public building engineer's work. The adoption of a prime mover utilising steam as agent for the conversion of heat into work has, we must note, left us with a most useful by-product—the exhaust with its 1000 odd units of heat per lb., useless dynamically, but directly serviceable thermally.

Certain public buildings, for special purposes, it is conceivable, might with reason instal condensing plant, providing always that a handy river or stream existed ; and there are ways of utilising the water circulated through surface-condenser tubes, for heating, and for baths, as yet little exploited ; but, as a general rule, non-condensing is indicated in the small power-houses of public institutions. The aim should be rather to maintain a fairly even load against the engines—a condition where condensing is of less importance. The smallness of the plant is also against condensing, even with turbo-electric sets. In a word, the system does not pay, and is seldom advisable for very sufficient reasons.

We are, therefore, left with steam discharging direct from the cylinders of—usually—small high-speed compound, variable expansion engines of, say 25-h.p. to 50-h.p., according to the scheme and size of the installation ; or small turbines may be installed.

The fundamental principles to observe under these conditions are a minimum of back-pressure and a maximum of heat regeneration—desiderata not strictly harmonising, since more or less obstruction to pistons, or "back-pressure," must under many systems be established. The accepted medium for heat transference

(from steam to water) is the so-called "calorifier," a variety of feed-heater, with copper tubes, preferably, steam regulation, and proper subordinate details for permitting the use of either live or exhaust steam, and for drawing away water of condensation. The use of the calorifier has developed greatly of late years for water-heating by steam for many purposes. An old system of working (in large public institutions) placed numerous calorifiers, here and there where convenience dictated, for the purpose of heating water for domestic use or for warming. Modern tendency is here, again, towards centralisation. It is an advantage on all points to group both the heating and supply calorifiers compactly with the engineering department generally, accessible rather from the engine-house, and

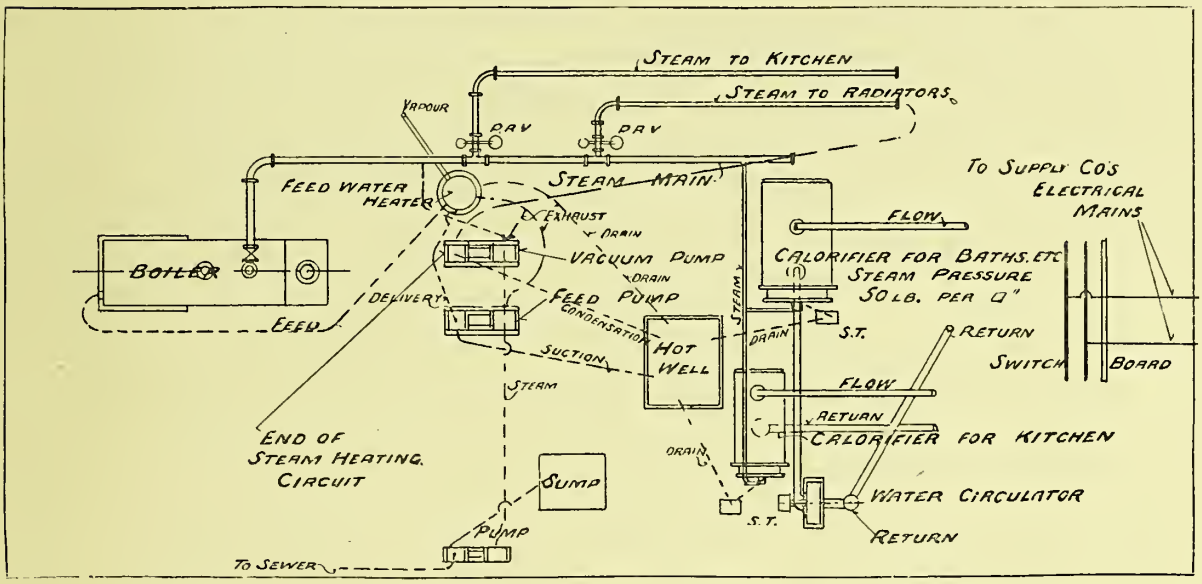


FIG. 5.—DIAGRAM OF HOTEL ENGINEERING. VACUUM STEAM HEATING: PLAN.
Live steam calorifiers for baths and for kitchen supply.

completely cut off, since it seems impossible, in any known form of heater, or on any plan of lagging or protection, to prevent the atmosphere of a calorifier chamber from resembling that of a Turkish bath. As an insurance against breakdown and for other reasons, it is in most cases necessary to make arrangements whereby the calorifier may be supplied with live steam direct from the boilers. A genuine spare calorifier is judicious in large and important works, although, as a matter of ascertained fact, the trouble experienced from this class of steam water-heater arises, not from defect in application of theory or design, but from careless handling, especially as respects steam regulation, excessive temperatures causing a hard scale to be deposited from many waters.

The necessity for a careful study of the calorifier department, and for a proper, workable connection for live steam from the boilers direct, is the more obvious when we call to mind how the modern metallic filament has reduced the amount of current, as against that required for the old carbon lamp. As a consequence, in public building engineering the steam power and the resultant exhaust steam have been in any given case correspondingly reduced. We have thus now-a-days less of the heat-affording by-product from the institution engine-room—less, that is to say, than formerly. It seems an obvious deduction that, if any given public building had, in the old days, just sufficient exhaust steam for heating apartments, etc., the substitution of the metallic filament has reduced the amount of steam heat available below that requisite for the duty.

This result has actually come about, and there are many large hotels where, from this cause, conditions now rule that the margin of safety is such that the possibility of abnormal weather conditions causes some pertubation in the minds of engineers-in-charge. The practical lesson from this is that less wasteful schemes of heating should be designed, and the auxiliary heating power available from the boilers direct be at all times ready and sufficient.

From the boiler-house as centre we have added, and tentatively considered, an engine-house, coal store and calorifier chamber, together with a well-house, pumping plant and water storage. This list gives the main features of a centralised engineer's department for the designed purpose of lighting, heating, etc., the various buildings of an institution, or the various apartments of a large building. As subsidiary features there may be an engineer's store, an engineer's office, stoker's room, and a small repair shop, with motor and one or two simple machine tools for ordinary engineering repairs. Exterior to this centralised department are matters coming under the supervision of the establishment engineer. He has to supply the laundry with steam—at reduced pressure—which is conducted to boiling-troughs and other appliances, and these machines and appliances are under his care so far as regards repairs and upkeep. The tendency in modern laundry engineering is towards simplification, both in plan and equipment: a plain rectangular building, divided as necessary by glazed partitions or screens, in preference to the old-time solid wall, is a practice favoured by experts; while the idea has been largely put forward that in hospitals, asylums and the like it is superfluous, excepting for sentimental considerations, to provide both inmates' (or patients') and an officers' (or staff) laundry. One may perhaps sympathise with the sentiments; but, apart from this, it is considered that the head laundress can more readily supervise and control one compact department. The question is open to some divergence in expert opinion, and, in any case, is one where the heads, or public authorities, will give decision. For this laundry or laundries the engineer

is required to provide hot and cold water and steam, heating and drying arrangements, motor and ventilating fans and the latest machinery, up-to-date washers and centrifugal wringers representing a constant quantity in all power laundries.

It is desirable that this laundry be arranged conveniently close to the central engineering department, whether we have under consideration a hospital, asylum, home, or large modern hotel. For one thing, the engineers are thus conveniently close at hand ; for the other, expense is saved in making the necessary connections

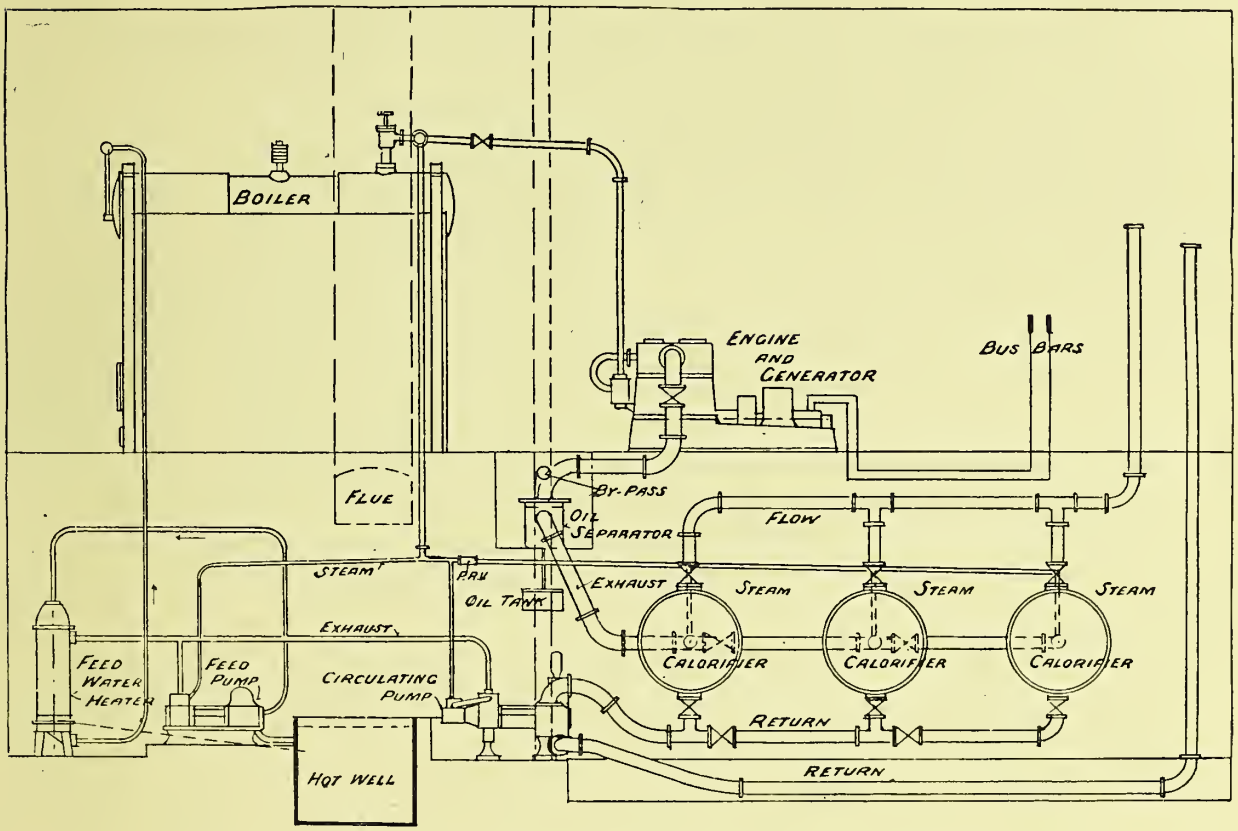


FIG. 6.—DIAGRAM OF BATTERY OF THREE EXHAUST STEAM CALORIFIERS, WITH AUXILIARY LIVE STEAM: SECTION.

for water and steam, and there is less loss by radiation and condensation. The general type and arrangement follows, on perhaps a larger scale, the establishment laundry of the public baths and wash-house, and differs from the genuine public wash-house, where the idea dominating the planning is the ingress, occupation and egress of the washers with their first soiled and then cleansed articles, together with convenient supervision by the superintendent. A necessary adjunct to the kind of laundry with which we are here concerned is an ironing-room, which

may be directly connected with the laundry proper, without fear of any injurious effects from vaporous emanations. The arrangement for drying clothes also comes in the engineer's province. The great defect in most of these devices results from non-appreciation of the laws of vapour-tension, and the potency of air-draught, as against mere heating, for removing moisture. On the plans too frequently followed much of the damp must be retained, and in these circumstances rapid and effective drying is impossible. Mechanical extraction or blowing of air is here a first necessity.

If it so happens that a laundry is considerably removed from the engineer's department, a small independent steam engine with utilisation of exhaust for heating may be indicated as a useful recourse; but the practice is retrograde—not in harmony with centralising principles. It is, however, not always possible to prevent a little local fuel-burning in laundries, even if merely for the ironing-stoves; for electric irons do not appear altogether to commend themselves to all users in practice.

The modern large kitchen—as in public institutions and hotels—utilises both steam, coke, or coal and gas. In any case, some steam appliances are adopted in such buildings, and if the kitchen department is fairly close to the engines, as frequently works out well on some varieties of plan, leaving residential and official parts to form separate and distinct groups, a reduced pressure supply is the best, direct from the main boilers; but in particular instances a small independent steam boiler may at times be found most convenient. The kitchen apparatus is in all public buildings under the supervision, as respects maintenance and repairs, of the establishment engineer.

The whole system of heating pipes, mains, branches, and radiators and radiating pipes, comes under the purview of the expert consulting engineer to design, and of the charge-engineer to maintain, control and repair, add to, and extend or modify, as occasion requires. The details of these prominent features in all large residential buildings will be dependent altogether, or very greatly, upon the scheme of ventilation (necessarily requiring to be co-ordinated with heating), the character of the establishment, and the existence, number, and size of the halls, wards, day-rooms, etc. Most doctors strongly advocate in hospitals a generous provision of open fires or cheerful stoves, in addition to the general hot-water or steam-radiator system, and we would, by the way, be glad to endorse this recognition of the influence of the mind and the nervous system on the more strictly physical. The open fire is a much-abused device, but must be considered a powerful mental tonic and most potent therapeutic agent, repellent of that injurious depression of the spirits of the sick, ailing, and advanced in years. Some day, possibly, the examination of the would-be physician will be directed first—

as a *sine quâ non*—to ascertaining whether he duly appreciates the effect of mind-condition on the physical. Among current superstitions the idea that some vastly disproportionate part of the heat of an open fire "goes up the chimney" persists, and doubtless will persist for generations.

To resume our general considerations: a marked characteristic of the public institution is the rambling (diffuse) nature of the plan. Hospitals especially, with their isolated blocks, cause the whole establishment to cover an extensive ground area. This loose, rambling feature of many public buildings has, perhaps imperceptibly, created a tendency in favour of hot-water heating rather than steam.

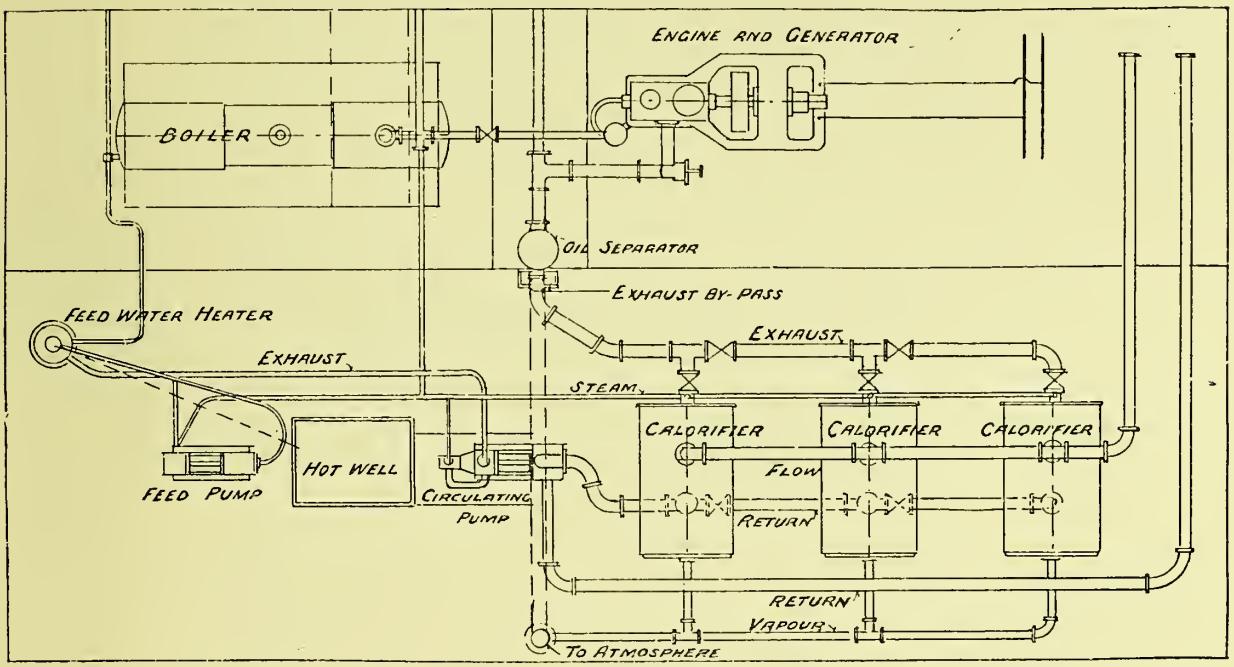


FIG. 7.—DIAGRAM OF BATTERY OF THREE EXHAUST STEAM CALORIFIERS, WITH AUXILIARY LIVE STEAM: PLAN.

The steam is indirectly the agent of heat *viâ* calorifiers, but the actual building-heating is a return to the elementary system practically of the greenhouse, and long a favourite in small public buildings, etc. A considerable impetus has been given to the hot-water system by the adoption of forced circulation. Under this plan the heated water is circulated through mains, branches and local circuits by suitable mechanical means, such as a centrifugal pump.

Several advantages accrue from this system. The water may be sent downhill, uphill, or on the level, indifferently and to any degree. The vigour of the circulation may be anything, and may be controlled—a plainly impossible procedure in the

gravity system. This latter needs as an essential a low-level boiler-house, or, at any rate, a low-level calorifier; for it must be remembered that one of the benefits of steam heating, or water heating, per calorifiers, is that the level of the stoking floor may be anything relative to the apartments to be heated, all requiring to be observed being that the calorifier, with the gravity system, must be at a sufficiently low level. Where, therefore, the centralised and grouped engineer's department cannot be conveniently located at a low level, the forced hot-water system is most opportunely useful. The requirements, given the boilers, are a calorifier or calorifiers, through which passes the exhaust steam or live steam as the case may be. The heated water continually passes round the mains and local branches to radiators, the lost heat units being restored and the temperature of delivery (from calorifier) automatically or otherwise controlled; for at each round of the mains and local circuits so much heat is given up, either usefully, to warm apartments, or lost by radiation. The system has been recently installed in many important works. It is well suited to exhaust steam, the calorifier being suitably designed.

A necessary condition of economy is a large heating area in the calorifiers, so that the greatest amount of condensing surface can be presented and a full way left for the residue of the exhaust, some part of which will necessarily go to atmosphere. It may occur to the reader that the system of heating here generally described has a natural prototype in arterial blood circulation. The force-pump may be regarded as the heart, and the mains as arteries, the returns the veins, while we may even compare the calorifier to the lungs as far as re-heating goes.

If we do not adopt some variety of this system, we are reduced to the old methods of either live steam at low pressure, at pressures less than atmospheric, or to direct exhaust steam heating, either with or without a vacuum pump, at the end of the system, or to the ordinary hot-water, and one or two modifications of this elementary method.

Some engineers question the policy of raising steam at all unless power is required, but there are advantages, and certainly many conveniences, attached to high-pressure steam generation with multitubular heaters (calorifiers) in lieu of the old hot-water "boiler," a device practically obsolete for extensive modern works. In small buildings, especially those not having many superimposed stories, the old simple hot-water boiler is well holding its own, a competitor, however, being low-pressure or atmospheric steam heating with special small boilers with auto-control of furnace draught. Libraries, galleries, municipal buildings, and the like are well suited with these simple systems of heating. Such buildings are non-residential.

It is in the inhabited institution on a large scale that engineering problems become involved and necessitate a lively reasoning before decision, if the whole is

to be mastered with a resultant convenience, and economy in working. The so-called high-pressure steam-heating, which, however, is invariably with quite low-pressure steam—as viâ a pressure-reduction valve from really high-pressure boilers, or from a special independent boiler—does not, at the present time, seem in great favour, several improved ideas having entered into competition, notably the below-atmosphere with vacuum pump or equivalent device.

Very great diversity of opinion exists among engineers on the question of the relative merits of hot-water or steam heating; but, where steam-generating plant is installed, there can be no hesitation as to the agent of the heat. It becomes merely a question of the best means of utilising the exhaust steam. The divergence of opinion concerns the actual use of steam or water in radiation. The

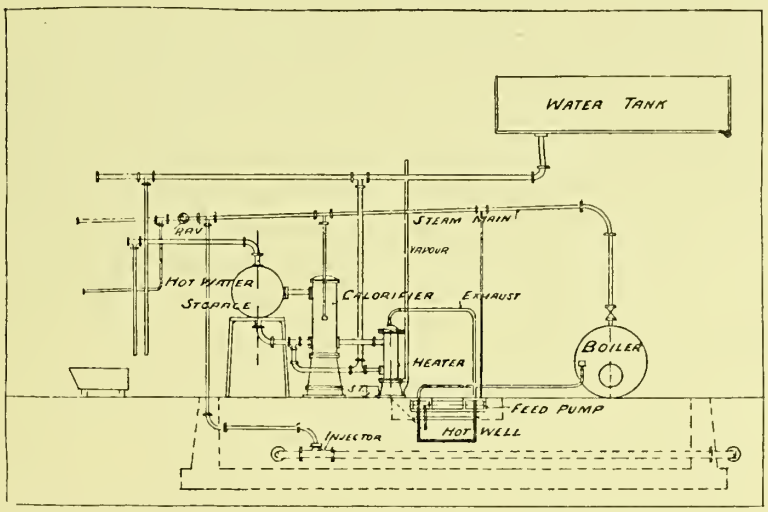


FIG. 8.—DIAGRAM OF ENGINEERING IN PUBLIC BATHS. LIVE STEAM CALORIFIER AND SPARE WITH AUXILIARY EXHAUST CALORIFIER: SECTION.

advocates of steam hold that it can be more readily controlled than is the case with a large bulk of heated water. The opponents of steam urge that the temperature of radiators is so high that the heating of the organic impurities in the air causes offence—an evil irrationally termed "burnt air." To meet this objection the champions of special below-atmosphere systems point out that at the reduced pressure the steam, or high water vapour, corresponds to a lower thermometric reading, thus avoiding the difficulty. Among the arguments advanced for hot water is that the condensed steam in the pipes has a singularly destructive or corrosive action; that the temperature may be anything according to control; and the evil of "burnt air" is avoided. The truth doubtless is to be adjudged much in harmony with the old saying that what is one man's meat is another man's poison—it is

impossible to recommend any nostrum for all conditions and cases. The proper course for the engineer planning a heating system is to bring under review every circumstance attending the especial case, and to keep an open mind until such time as he has mastered the whole problem in all its aspects. Economy, efficiency and low cost of upkeep have to be brought into line with a constant quantity—first cost.

Air heating by stoves and delivery by ducts, if not common, has at times its special uses ; but the system must be adjudged fundamentally wrong. What we require is radiant heat and relatively cool air to breath—the genial May-day, or the open fire and open window as a type, however difficult to adapt, yet on the soundest hygienic basis. Compared with the ideal, all modern public buildings have defective heating, as any observant and sensitive visitor to such quite well understands. In practice we get the best results practically possible.

The subject of building-heating cannot rightly be considered apart from that of ventilation—and this subject is a thorny one. Heating and ventilating naturally co-ordinate. Hence, it has resulted that among professors of the art the terms are generally assembled as a definite couple—inseparable twins. The science, in spite of a plethora of formulæ and treatises, is yet empirical. Data are unsound, and must be considered likely to remain so, by reason largely of the perversity of the winds that blow—that, defiant of daily weather-prophets, back east and west when we had expected consistency from south or north, and play and eddy round pavilions and wards, to the despair of the ventilationist. Round so-called natural ventilation on the one hand, and artificial or mechanical on the other, there rages a perennial battle-royal. The advocates of "natural" ventilation base their schemes on the fact that heated air will rise, and that the atmosphere of a heated room is more rarefied than the external atmosphere. This condition of affairs, it is argued, creates a virtually automatic ventilating engine, rendering actual rotative fans and blowers unnecessary. The outlet for the vitiated air is, under this main system, mostly at the highest level ; and it is assumed that these openings, by their mere existence, or coupled preferably with specially devised static contrivances assisting exhaustion or air abstraction, are sufficient to cause thorough ventilation of the apartment.

The mechanical system of ventilation embraces *forced draught*, virtually, and requires fans and blowers, either acting by pressure or by exhaustion. Either the fresh air is blown in and the vitiated air finds its way out, or the latter is extracted and the pure air drawn in ; again, both fresh air is blown in and foul air forcibly extracted. The system as a whole requires either ducts for fresh air or for extraction, or for both, and the method of heating the apartment so ventilated varies considerably. In effect there may be either a purely warm air supply or a

combination system. The fresh air is usually admitted low, but sometimes at a high level, and the extraction is generally at the highest point.

A system of comparatively recent introduction is called "plenum," as signifying a state of fulness, and actually working at a slight pressure above the atmospheric, and is found serviceable in large halls and places like theatres, densely inhabited for a short time by quiescent audiences. Under this system the air is generally first warmed and then forced into the building, causing excess of air—above the pressure of equilibrium under conditions—to leave the apartment in a constant stream. Under this arrangement low-level exits may be provided.

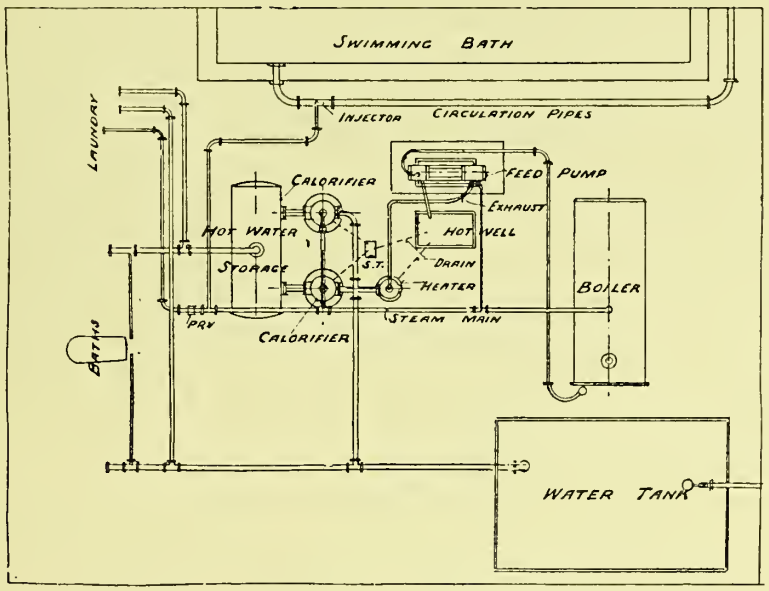


FIG. 9.—DIAGRAM OF ENGINEERING IN PUBLIC BATHS. LIVE STEAM CALORIFIER AND SPARE WITH AUXILIARY EXHAUST CALORIFIER: PLAN.

It is useful to note—as suggestive—that an interesting system of ventilation is that generally employed in modern Turkish or hot-air baths. Here, inasmuch as the temperature of the respired air is lower than that of the sudatory chambers, it is made an assumption that breathed exhalations will tend to fall, and that the CO_2 in masses will assist the action. On this line of reasoning, one places the extractor gratings at the floor-level. A more practical explanation of the necessity for these arrangements is forthcoming in the fact that inasmuch as the wholly scientific method of heating on the old Roman bath hypocaust system has been abandoned by Western and modern nations, even if maintained to a certain degree in the East, to supply highly-heated air to rooms having a high-level outlet would require vast quantities and an enormous amount of coal-burning, the practice

being, in a sense, as though one would fill a balloon mouth upwards. In order, therefore, to avoid this, it is the custom in naturally-ventilated hot-air baths to make low-level exits and connect these by flues to an extraction shaft. The body of rarefied air in this shaft, as in an ordinary boiler stack, will keep an automatic air-flow and so practically ventilate the bathrooms. The fresh air is by this means drawn in, over and around the furnace and its air-heating flues.

The pros and cons of ventilation form an evergreen topic. Looked at broadly, the natural ventilationist has a machine that largely, if not entirely, must depend upon, or be chiefly influenced by, a most variable natural force—wind current. The efficiency of this engine must often vary hourly; indeed, every few seconds or minutes. At one time the air outside is calm, at another a gale is raging. Nevertheless, as a practical device, much satisfactory ventilating work is accomplished on this apparently crude and rudimentary system. As a contrast to this, the general idea of mechanical ventilation seems scientific and reliable, and independent of wind currents, and so at times it may prove, but by no means universally so, there being notable failures. The eccentricities of the same uncontrollable wind currents, and the apparent impossibility at times in matters of ventilation of reconciling theory and practice, frequently upset calculation and formula. Hence it comes about that the apparently very simple matter of keeping any given apartment at a comfortable temperature and supplied with pure, fresh air is one full of pitfalls for the unwary, and requiring, rather than quasi-science, a liberal application of common sense.

The boilers employed by the engineer in public buildings and institutions range into two main classes—the real high-pressure steam-generator and the small boilers for purely building-heating duty. The latter class may be subdivided into steam, low-pressure boilers, and hot-water "boilers." Among the high-pressure generators employed in public buildings for heating, lighting and power purposes are vertical boilers of various kinds, "shell" boilers—Cornish and Lancashire—water-tube, "dry-back," and marine "Scotch" boilers. All are useful in suitable conditions, but the most generally adopted for institutional work are the Cornish and the two-flued Lancashire. The sectional and other small heating boilers refer rather to non-inhabited public buildings.

A separate class might be made of the large shell "boilers," or water-heaters, but the use of such is falling into desuetude. The practice in establishments erected under the Baths and Wash-houses Acts was to provide two or three or more large shell boilers, a part of such equipment not being employed as steam-generators, but for heating water. At the time these boilers were installed, electric lighting had not been generally adopted, so that the only power required was, say, ten to twenty effective h.p., for driving laundry machinery. In these

circumstances, and seeing that the only other steam required was for the boiling-tanks in the laundry, the practice was to keep one boiler under steam and one or two for heating water for supply to baths and laundry. In those days, too, it was customary to heat swimming-baths by circulating the water during the night through large boilers, or by supplying fresh hot water from such boilers. A frequent position, therefore, was one boiler under steam, at about 60 lb., two supplying hot water, and one out of commission.

The development of a system of heating swimming-baths by means of a special steam injector and circulating pipes, and the growing practice in large public buildings of generating electricity, gradually changed all this. The modern system includes two or three powerful steam boilers, at say 100 lb., which supply any electrical generating and laundry engines, steam at reduced pressure to the laundries, and at high pressure to the "swim" injectors, and heat water for baths and laundries supply by means of calorifiers. All exhaust steam is carefully utilised, any deficiency being made up with live steam at reduced pressure. When the baths do not generate their own electricity, live steam will be supplied to the calorifiers.

For the whole duty here indicated, large Lancashires have been mostly used. The easily-predetermined load, and its known variations at different seasons, make such boilers highly suitable, but the water-tube boiler is also suitable, and has made considerable progress. The Cornish type, much used formerly, has, however, almost disappeared for important work, for one reason that smokeless combustion is difficult with single-furnaced boilers, where careful alternate firing of the double flued Lancashires avoids this difficulty to a very great extent.

The rapid advance of the genuine water-tube boiler has been due to the growth and development of the large power-station. Far more elastic in steam-raising potentiality, it has, for electrical generation on a large scale, made great inroads into the business of shell boiler construction. In foggy towns the value of such a steam-raiser is great. It is not only readily responsive to peak load demands, but may be started from all-cold in a fraction of the time necessary, or at least highly advisable, to be expended in getting cold shell boilers ready for work.

It requires to be ascertained how far these considerations bear on the present subject, which is the scientific lay-out of an efficient, economical, and durable scheme of lighting, heating, and general engineers' work in large communal buildings.

It is not possible to lay down dogmatic rules as to this or that type being the best. The whole circumstances of each special case require to be reviewed. What is the duty? This must obviously be the first question, and obviously,

again, the answer cannot be made offhand applicable to all cases alike. Too much circumspection cannot be shown; the whole duty is compound, and the factors are variable. One building requires mainly heating, another mainly lighting, and again, others heating and lighting in varying degrees or proportions, according as to whether we are dealing with a hospital, infirmary, workhouse, home, hotel, or any other of the manifold varieties of modern institution.

A controlling point is whether or not the establishment is to generate electricity. If so, what is the estimated maximum load, the average load, and where is the peak? All these points bear on the type of steam-generator; and, having arrived at the total lbs. steam required as a maximum duty, and having conceived an idea of a suitable type for the given institution, establishment, or concern, it still remains to be seen that this meets any special exigencies of space, since, for example, far greater power per cubic yard of space available can be obtained from multitubular than from shell boilers; and, although we may decide that (as in a workhouse) certain considerations, such as inmate stoking, render a plain shell boiler most suited, the exigencies may be such that we perforce must adopt the tubular, and perhaps justify our selection by the reasonable argument that unskilled attendance on large steam generators is scarcely rational.

Many other questions will arise in the mind of the engineer confronted with the problem of specifying the most appropriate boiler for a given purpose, so that it may be taken that it would be erroneous to lay down that this or that is best for specific buildings. Those having authority to speak, from great and special experience, are strong advocates of Lancashire boilers in poor-law institutions, hospitals, and asylums; and generally in large countryside public, municipal, and privately-endowed buildings of the institutional kind, where a great part of the duty of the boilers is heating, we find two-flue shell boilers predominate. If the demand for steam is small, the duty is performed by plain Cornish boilers. It may be that some part of the general appreciation of the shell boiler (as against the water-tube) may be assigned to a kind of mental momentum or persistence of old idea and custom, for we find this principle a factor in walks of life other than public building or institutional engineering. It may be assumed that, by habit, many become accustomed to draw an oblong, on plan, labelled "boiler," and to consider the Lancashire the only wear.

Where electric lighting forms a large part of the load, and where there is a heavy peak, and a fog bank would create a sudden and considerable demand for steam, most engineers would favour the water-tube, and hence, in the largest modern hotels, not taking public current, a battery of water-tube boilers seems the thing. In such cases the lighting factor may be paramount, but directly this vanishes the case stands differently; as the Savoy Hotel, with four really powerful

water-tubes, and the new Strand Palace, opposite, where the whole steam-raising complement consists of three small loco-type boilers. It is fair, however, to add that in the case of the Savoy the lighting load includes the adjoining theatre, while the two buildings are not of equal magnitude.

The practice of generating steam at pressure, in lieu of employing large hot-water "boilers," has been an all-round economy in first cost, and especially has the system of centralising calorifiers tended towards this result; many hospitals and asylums, having re-modelled their whole steam and power plant, have effected great economies in coal consumption. An old arrangement in such buildings was a multiplicity of calorifiers at different points, live steam being conducted to these. As many as forty of these water-heaters, thus dispersed, have been put down, and on scrapping the lot and arranging one, two, or three, on modern lines, and with the utilisation of exhaust steam, together with a system of forced circulation, great saving has been made, and not only in annual expenditure on fuel.

The method of handling and working boilers in manufactories, works and commercial undertakings is a case by itself: it has no significant bearing upon our present subject. High pressure, it is true, indirectly leads to economy in heating by enabling less bulky appliances—as calorifiers—to be installed for the work, and in the case of the heating of public swimming-baths a good head of steam is justified by the peculiar duty—injection; but, inasmuch as the total heat of steam and its variations is not so important as the general consideration that there is what might be termed a set average of steam-heat per pound, moderate pressures, say 100 lb., are highly suitable in establishments where more or less incompetent stoking may be employed.

The best pressure in boilers for public buildings and institutions depends on (1) whether power is required for lighting, and (2) on the use or not of exhaust steam. Where there is no power, except for operating a feed-pump or small engine, and economy in outlay is required in the steam-raising and steam-condensing (for heating), and where the space that can be allocated to an engineer's department is small, the indications are for high pressure in both boilers and calorifiers; for under these conditions a dense steam atmosphere surrounds the heater tubes, and the potential condensation per square foot of surface is proportionately high. In such circumstances there would be, say, 100 lb. in the boiler, and 100 lb. less drop in the heater. The system requires less tube area, and necessitates a high velocity of flow, and well suits, therefore, forced circulation of the kind before referred to.

The case above considered is elementary, but in so far is an indication for reasonably high pressure. Take the more elaborate example of electrical genera-

tion with exhaust heating. High pressure, with suitable prime-mover design, means high economy—increased thermal efficiency of the boiler and engine, as a combination. Every pound under any given pressure of evaporation, when used in the engine, lowers the economy—increases the outlay of coal per unit generated. The amount of heat rejected in exhaust does not practically vary, being a factor determined solely by the load, or chiefly dependent on this.

In a battery of boilers it is well to maintain equable pressure in the component units, so that, even if building-heating suggests low-pressure, it is inconvenient and undesirable. But the case stands that the question of building-heating is met by the reducing-valve, or by simple throttling, so that again the advantages are with high pressure, or, at any rate, no valid objection is discovered to reasonably high pressure. It may be noted that all suitable pressures for heating, calorifiers, water supply, culinary and laundry purposes, are in modern practice adjusted by reducing-valves, so that the choice of an efficient variety of this device is important in the class of engineering with which we are concerned.

In all questions of hot-water heating and supply it may be considered that the case stands that the heating engineer, having added much sensible heat, and bringing temperature near or well towards 212 degrees, may pass on this to the power engineer, who "tops up," so to speak, with extra heat and gets his energy, then hands back to the heating man, who utilises the residue of heat; or, more correctly, the power engineer adds both sensible and latent heat, utilises the kinetic energy, rejects a vast amount of latent heat, to the heating engineer, who conserves as much as possible of the sensible heat and hands back to the power-house. In any event, it generally results that, where much building-heating is required, the proportion of heat represented by effective power at the engine crank-shaft is so small that this power may be said to be gained practically for nothing. This is the practical point of the exhaust steam method.

As a result of these considerations, it might be laid down that simple heating by boilers and calorifiers justifies reasonably high pressure, whilst where energy is required the high pressure is a necessity.

We have considered type and pressure of boilers suited for institutional and kindred engineering work. It remains to study the conditions governing the question of the potential energy of the boilers—their requisite size and capacity as generators of steam. In new buildings the basis of calculations will be the schedule of the power, light and heat, as furnished by the promoters of the scheme.

The total boiler capacity will be a measure of the total lbs. steam required per hour, after allowing an excess over net calculations for various known and indeterminable (in fine detail) losses, in the main represented by undesigned and inopportune condensation. To this should be the added margin as definite spare.

The question of spares in all kinds of installed plant and machinery is always one of debate, but generally it is held that one boiler out of commission on the utmost maximum demand is sufficiently correct practice. It must be advanced that the practice of spare this and that throughout plant of this nature is an unnecessary initial outlay, the principle to observe being that *something* must be chanced in all life's arrangements and planning. Moreover, a breakdown in an institution is not to be put down on the same plane as failure in a public-supply power-station, for example; and in any case the question of spares does not affect the estimates to meet known, or closely assumed, duty.

In the elementary work of heating unpretentious buildings by hot water, certain sizes of "boilers" are recognised and tabulated by makers as competent to heat such length of pipe, or number of radiators, or radiating surface, or to warm a certain cubic space, or maintain a certain temperature when the thermometer outside registers so many degrees. These apparently crude tables are really the result of actual practical experiments and experience, and are useful; allowance being made for the co-efficient of commercial competition—as when we employ an approximate rule in steam heating, and say that one-third pound steam is required per square foot of radiating surface. There are numberless figures and elaborate formulæ put forward with respect to heating to be found in numerous text-books and treatises, which may be found misleading unless common sense enters into all calculations on these and similar heating and ventilating data. What the engineer requires first to do, is to gain a comprehensive knowledge of the conditions ruling day and night in the establishment or proposed institution or building. He needs to assume a load and temperature curve for the twenty-four hours. It is obvious that, although probably the subject is considered by professional engineers of less dignity and importance than, say, estimating for the plant in a genuine power-house, the problem is more involved. It is easy enough, given the requisite data, to estimate the steam required for a set of engines of known steam consumption. As a rule, doubtless, the really difficult problem of correlating facts and co-ordinating working, of various machines, is avoided, and a solution provided by provision in excess; but, if this is a practical solution, it is not just to authorities or other paymasters; and, as something fundamental, careful provision by pre-arranged-for additions in building and in plant is a scientific procedure, where excessive first outlay directly results from either carelessness or ignorance, or both.

Besides the size of the complete whole, there is the further question of the number of units comprising the whole boiler equipment. For efficiency of boiler, we keep the units large, for convenient working we should provide relatively small. Two large boilers, one always out of commission, is a very common

arrangement. Three units often, in average public institution work, make an ideal arrangement, since either can be spare. Spare, however, we cannot but think, in this class of engineering, might more often be regarded as emergency plant —as, say, during excessive frost, long continued, accompanied by persistent fog. Under such quite abnormal conditions—in this country—the suggestion here is that what is otherwise a spare might be put pro tem. to work. It should be clearly pointed out to the reader that this is not the ordinary view, but the suggestion is given as something to be considered, when suitable cases present themselves, by the thoughtful designer, bent on arranging economically and efficiently for his client. One good result could come about from this fundamental arrangement of plant capacity. The engineer-in-charge would be prompt in repair, and aim at, as he should, having his spares at all times in equal condition to his normal working machines and appliances. If under this arrangement he could always manage comfortably, it would not only be a testimonial to himself, but an elegant proof of the capacity of the designer of the plant. One cannot hold back the thought that habitual provision of excessive spare indicates, primarily, want of faith in one's own plans; and that this type of designer in excelsis would require, on a voyage from Liverpool to New York, a spare liner always within easy hail.

It is obvious that a great factor in the question of boiler equipment in large inhabited institutions is the variation of temperature with the varying seasons. Naturally, the normal summer's day load-curve is insignificant when compared with that attendant upon a foggy day in midwinter, but the irregularity and unforeseeable change in climatic conditions in this country make it necessary to be at all times prepared for emergencies. The variation of solar light, as such, and of appreciable heat, roughly, or frequently, co-ordinate; so that coal-consumption curves, in buildings requiring both light and heat, bear some approximate relation to the solstices. As a rule, therefore, during, say, five months of the year, some 60 per cent. of the boiler-power may be unnecessary, presenting thereby an opportunity for charge-engineers to make any amendments and serious repairs. Let the position be noted in reference to what has been said above. It suggests this as corrollary: no excuse for breakdowns (from carelessness or neglect), and no reasonable fear should be present during those abnormal days when working every boiler —i.e., spare as well—if the opportunity for thorough overhaul has been seized. The question of the ratio of working plant to the designed and true spare therefore stands on a different footing to, say, that of commercial work, all practically under full load throughout the working year.

Summing up the above considerations, it would appear that whether three, four or five steam boilers are the total provision, one in any of these cases is ample spare, and that even this might, by so ordering things by the superintending

engineer, be always fit for working during winter months, if absolutely pressed by circumstances that are abnormal but within the range of possibility. The one system may be called designed spare, the other a quasi-spare provision.

If the system comprises only allowance for normal maximum, the spare comes in as auxiliary. Variations on the normal are met by elasticity—easy and brisk firing. Neither boiler nor engine, any more than man, is fit to work continuously at full limit of capacity, but neither good boiler nor engine, nor sound, healthy man or animal, is injured by at times putting forth generous energy short of that stress that develops actual strain. The spirit of this may be emphasized. Taken in conjunction with the idea of occasionally working actual plant and spare at the same time, it may be of assistance in suitable cases in many problems. Every pound's worth of machinery saved is not only a saving in first cost but in maintenance, and although a lack of boiler power and habitual forcing is against all rules, temporary stirring up of energies may be perhaps as good for machinery as for man. Without necessarily decrying the basic principle at issue, it is evident that where a boiler is a designed and absolute spare, a sum of 1000*l.* or so may have been outlaid on a piece of apparatus virtually *never used*—a mere insurance against something at a cost of 50*l.* per annum, ignoring incidental costs, calculations for depreciation, etc.

The duty before boilers may be narrowly estimated, for any given institution, by a study of the conditions ruling by night and by day in similar institutions. In detail the whole is made up of certain individual loads of which satisfactory curves could be assumed. The peaks will not, in ordinary circumstances, coincide, which must be regarded as an advantage. If the matter were controllable, the object would be to flatten out peaks and maintain a regular load, to obtain a high load factor, much as the object of the power-house engineer is to obtain a heavy day load. Not precisely so, because here the object is (in a sense) *to burn as much coal as possible*: in other words, to make as much business as possible in the sale of electrical units. The object of the engineer-in-charge of public buildings and institutions is to reduce, as far as possible consistent with efficiency, fuel-burning, for economy's sake and for his own credit. This he can best do directly by ordinary engineering skilfulness, and indirectly by so arranging that he may not work machines at uneconomical load. As with the power-house engineer, he desires a high load-factor. If he could smooth out the peaks he would be glad to do so.

A normal institution lighting load will resemble generally, in main mass, the power-station curve, modulating with the seasons. It will show its maximum indication in midwinter, with certain unusual characteristics in the milder and summer seasons, such as fogs. This general condition suits roughly, in that the

more light the more exhaust for building-heating. The other component of the load against the electric engine sets is the motor load, the work of operating one or more, or all, of the motors for wells, pumps, lifts, laundry machinery and ventilating fans. It will, in an ordinary institution, average very closely all round the year at approximately the same, day in and day out. As a rule the most important of these several duties is the actuation of laundry machinery which may commence at 8 a.m., and with an hour for dinner interval, shut down at 6 p.m.

The object of first considering a lighting load is to ascertain what amount of heat is available in the exhaust, since, supposing that the amount of energy required was such that the exhaust afforded us sufficient heat for all times and all seasons, the total boiler-power necessary to provide would be the lbs. steam we required for the engine. Unfortunately, this is seldom the case; perhaps in the winter five times the amount of water needed in the electrical work is required to be evaporated for supply to the building-heating calorifiers. A simple method for a large undertaking is to ignore the electrical business, and provide boilers sufficient to do the heating; and as it stands that more than three-fourths of the heat originally put into the steam remains usefully in the exhaust, we have a certain justification for estimating first the building-heating, on the knowledge that whether or no any of the steam passes through engines almost all the steam heat is available.

The whole work of the boilers, at any given moment, is the total of steam going to engines, either electrical or for laundry machine or pumps, plus the live steam required as such. This will be steam to laundry, to kitchen, and, say, to a building-heating calorifier and water-supply calorifier. If we examine any curve giving the units generated for twenty-four hours, we can see how much exhaust is available, and this will correspond approximately to the rise and fall of the curve.

Engineers should endeavour to get a grasp of whole problems. This, judging by visits to many public buildings during years past, seems the great want. It is easy to specify engines and boilers, and pipes and packing, but that is not the main use to employers of a consulting engineer. Such a one is required to brood over the building-engineering problems, as a whole, to the end of saving in first cost and annual expenditure.

The several diagrams given herewith represent tentative sketches—first ideas of schemes. Rough notes of this kind are more to the point in the first inception of an institutional engineering plant than neat draughtsmanship on the actual, scaled building plans. It is a simple matter to arrange for manufacturer's appliances and apparatus. Clients—authorities and others—look for something more than this. The skill of the institutional engineer and expert in building-

engineering generally is shown rather in the correlating of units and parts, to the end that the whole may be made an efficient, economically-working *machine*, taking in so much coal, giving out so much power and heat, and well utilising all by-products, such, for example as exhaust steam. To make, consider, remake and reconsider rough diagrams, until the problem is mastered as a whole, seems the right method for anyone engaged in the lay-out of engineering plant for large communal buildings. With the idea of emphasizing this point, the diagrams, obviously crude and incomplete, are here given.

Figs. 2 and 3 show a Lancashire boiler, with economiser, the latter an effective coal-saver if close to the boilers and kept clean. A high-speed engine and generator supply electrical energy to motors and lamps as indicated. The heating is on the forced hot-water system. The scheme assumes a small lighting and motor load ; the bulk of the heating is therefore by live steam in calorifiers ; but so much exhaust heat as is available, from the main engine and pumps, goes to a separate exhaust heater or calorifier, which assists in building heating. Both the supply and heating circuits have forcing pumps. All condensation returns to a hot well, whence the feed pumps pass the water through the economiser, together with any necessary make-up cold feed. The well pumps are actuated by electric motor, a three-throw pump being indicated, and a sunk well understood. The water is raised to the main tank, and hence distributed to subordinate tanks in the institution buildings, by a water main pipe indicated on the diagram as entering the subway connecting to the several building blocks. Steam traps are provided to the high-pressure calorifiers, and a pressure reducing valve is fixed on the main to the laundry, where steam is required for boiling troughs, etc., and for heating coils as indicated.

With such a roughly-sketched diagram before him, the designer can weigh all points of his scheme, its action and economics, before considering details of plant, and before even putting a line upon the accurate building plans of the architect. For example, careful consideration of the general proposals indicated in Figs. 2 and 3, and an estimate of the exhaust steam available may show that the live steam building-heating calorifier may be abandoned, and a more effective exhaust-heater substituted for the couple of heaters originally proposed. Wasteful lengths of steam main may be saved by a little re-organising of the general scheme. Again, it might be better to provide both live and exhaust steam to the same calorifier or battery of such. In the diagrams, Figs. 2 and 3, the calorifiers, etc., are indicated as in a basement ; but with the circulating pumps the whole might be conveniently arranged on the same level as the boilers ; while the requirements of the condensation mains may suggest a return to the basement arrangement as originally proposed.

Figs. 4 and 5 give diagrams of a scheme for hotel engineering with vacuum steam heating. It is noticeable that loco-type boilers are here proposed, and rationally under the conditions; for, inasmuch as electrical energy is obtained from the supply company's mains, no private lighting engine is required, and no oiled steam; while direct steam heating being employed, much clean feed-water is used over and over again. Ground area in large central city hotels is costly. All these considerations justify the adoption of a tubular boiler, if such is convenient for the duty; and this, by reason of the absence of electric lighting work, is relatively small, and does not demand great boiler power.

The two calorifiers indicated are kept well up, enabling the hot well to be placed so that an actual head may exist in the suction-pipe of the feed pump. Although in theory the steam should enter a vacuum heating circuit at zero pressure, or that pressure indicated by gauge on the vacuum pump suction, in practice a few pounds per square inch are maintained at this point—the live steam entry to the circuit—and for this reason a pressure-reducing valve, set for 50 lb. to 4 lb. reduction, is here indicated. The whole circuit of pipes and radiators is kept below atmosphere by the vacuum pumps of special construction. The steam to the kitchens is reduced only to 15 lb., as necessary for the effective working of the several culinary appliances. A full head of 50 lb., less drop, is maintained in the kitchen calorifier, and also in the baths calorifier, thus making a small heater perform a high duty. The circulation through the kitchen calorifier is automatic; the other heater, being connected to a long and tortuous system of branches, etc., has forced circulation by a small centrifugal pump, preferably motor-driven. In hotel work, kitchen engineering is naturally of paramount importance, arrangements being thorough and a refrigerating plant now generally included. In large hotels generating electricity, Lancashire, dry-back and water-tube boilers are frequently employed, all exhaust steam being, in the winter at least, fully utilised.

Figs. 6 and 7 show a water-tube boiler and electric-lighting engine, with exhaust conducted to a main, connected to three interchangeable calorifiers. A more generally useful application of a battery of three exhaust heaters is given in Fig. 38, Chapter X., with all necessary piping and valves, for both supply and heating duty. The feed pump and circulating pump exhausts (in Figs. 6 and 7) go to the feed-water heater. The general scheme here indicated is perhaps more suited for a public bath-house as exemplified on a large scale at the Shoreditch Public Baths, and utilising the power station exhaust steam in heaters, supplying hot baths water as their sole duty. In the diagram, condensation drains, omitted on the drawing, would be required. Auxiliary live steam is shown to each heater.

Figs. 8 and 9 show a Cornish boiler, solely for baths supply, i.e. there is no power beyond feed-pump actuation. The laundry machines, it is assumed, would be

driven by public electricity supply, and main's water taken. This simplifies the plant. The whole duty is supplying steam for the laundry and for heating the swimming bath, and hot-water baths' supply. Live steam, at say 60 lb., is taken to a calorifier and to a corresponding spare unit. These are coupled up to a horizontal hot-water storage tank, a feature of importance in baths engineering. Too often this valuable addition has been omitted, to the great distress of superintendents. Under the arrangement in Figs. 8 and 9, either of the vertical heaters can be in use; but, being for high pressure, cannot be connected with exhaust. To economise therefore, the feed pump exhaust is taken to a separate small heater, coupled in series with either of the live steam calorifiers. Suitable stop-valves and by-pass, not indicated in the small diagrams, would be required. It is of great importance, in such a plant as indicated, to provide effective automatic steam regulation on the calorifiers, otherwise early trouble from scale may be anticipated. Condensation returns to the hot well and is pumped into the boiler, with suitable make-up cold feed. One steam-trap serves the two calorifiers. Live steam is taken to an "injector" and circulation pipes for heating the swimming-bath, details of the system suggested being given in Chapter XIII. The circulation through the hot-water baths system is intended to be natural, and may either be complete, or a small return pipe provided just to keep movement in the circuit. It is now common to include a forcing-pump in baths engineering.

We would repeat that the idea of these diagrams is to suggest recourse to similar rough sketches when first scheming building-engineering plant. The smallness of the drawing, and the bringing in compactly of all features of the scheme, facilitate a grasp of the whole problem. It is as though we stood off from the whole sufficiently far to lose sight of detail, and leave visible only main controlling factors.

CHAPTER III.

VERTICAL BOILERS FOR INSTITUTIONS.

The small ground area occupied by the vertical boiler renders it an invaluable steam-generator for special institutional needs, notably on occasions when some medium-sized heating appliance is required between the large shell and an ordinary sectional boiler; and as a recourse for increased steam-raising where only an odd corner is available for its accommodation. It is largely used for kitchen work, some separate service of steam-supply being here often better than reliance on the main boilers. Fig. 10 shows the arrangement of a vertical boiler at Dowlais, Glamorganshire, from plans by the author. The Wimborne Baths were projected and carried out to provide bathing accommodation for the employees at the steelworks.

Fig. 11 is a block plan of the baths building and boiler-house. The example affords a good illustration of the uses and special conveniences of the vertical boiler for water-heating by means of a high-pressure steam calorifier. The arrangement of pipes is necessarily not a model one, because of the peculiar circumstances that attended the carrying out of the baths scheme.

Fig. 11 shows that the baths were planned to be built on the steelworks premises, next to a yard entrance. On one side of this entrance were two Lancashire boilers, whose duty was to provide for a set of pumps. The original intention was to take steam from these boilers to a calorifier in the baths basement. The calorifier chamber and baths were already well progressed, when it was decided that it would be inconvenient to take steam from these boilers. This led to an awkward position. It was necessary to preserve the yard entrance; the baths building could not encroach on the works premises; and the only site for a boiler was the small space between the old boiler stack and the road, a space not conveniently large enough for any kind of shell boiler. It was therefore decided to adopt the vertical type, and a careful investigation into all available forms of such led to the adoption of the well-known Cochran boiler. The space available for housing the boiler was separated by the yard entrance from the baths. A subway was therefore constructed for pipes underneath the entrance to the works. Referring to Figs. 10 and 11, it will be seen that the boiler

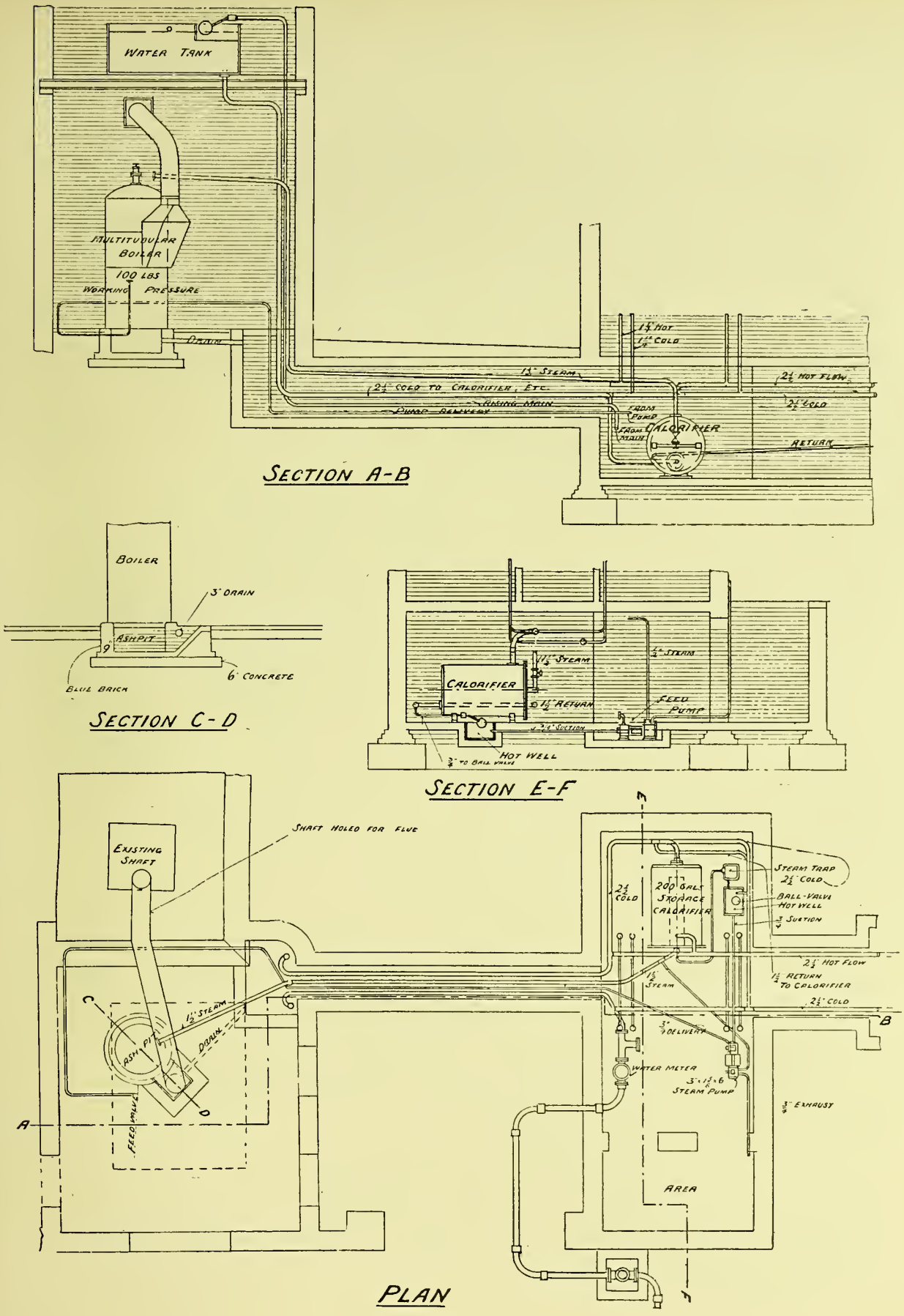


FIG. 10.—PLAN AND SECTIONS OF SMALL BATH-HOUSE WITH VERTICAL BOILER AND LIVE STEAM CALORIFIER.

was placed close to, and utilised, the old Lancashire boiler stack—one of the great conveniences attending vertical boilers being thus demonstrated. A boiler-house was erected, carrying a water-tank above. The water was brought in as indicated to a suitable stop-valve, beyond which a reduced diameter of pipe formed a rising main, being led, under the subway, to the tank with ordinary ball-valve control. The supply pipe went from tank under subway to the calorifier chamber. It supplied the calorifier by a connection to the return pipe of the circulation system, and also the cold supply main down a subway under the bath to the bath-valves over.

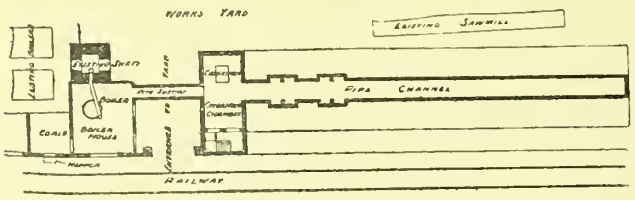


FIG. 11.—BLOCK PLAN, WIMBORNE BATHS, DOWLAIS, GLAM.

The main steam pipe passes under the subway, and goes to the auto-regulating inlet-valve to calorifier steam tubes, a branch pipe going to the small boiler feed-pump. The hot-water flow from calorifier ran down the baths pipe-subway, alongside the cold supply pipe, and at the end of the system a return pipe was provided to ensure circulation, and avoid a dead end in the supply pipe, all as indicated on the drawing. The calorifier steam chamber was connected to a steam trap discharging condensation water into a hot-well, whence water flowed to the suction pipe of feed-pump. A small pipe and ball-valve permitted fresh additions to the hot-well supply as necessary. What might be called a deformation in the steam cycle here took place, for the exhaust of the pump was wasted to atmosphere, whereas it might have given heat to the boiler feed-water.

Although, as has been pointed out, not a model of pipe arrangement, the whole is a useful illustration of high-pressure calorifier work, giving all details as they were carried out, and as the plant operated. By virtue of the 100 lb. pressure of working, a small, compact calorifier was permissible for the duty in a cramped space. The use of steam, again, permitted the boiler to be at a high level, independent of the calorifier level. The boiler feed was the condensed steam; hence, clean boiler surfaces and clean calorifier tubes were ensured. The cycle of events is correct and complete, save for the non-utilisation of the pump exhaust.

The boiler is mounted upon a blue-brick walled ash-pit, having a drain or overflow permitting water to be kept in the pit; the whole upon a bed of concrete. This forms, for a self-contained vertical boiler, quite a luxurious ash-pit and foundation; all that is really required being a firm, solid floor, or a ring of brickwork, say, over this. Herein is demonstrated the simplicity and inexpensive

nature of vertical boiler-setting. Moreover, it is no small gain that the external parts of a boiler can be so thoroughly and conveniently examined. These advantages, alone, should more often induce institutional engineers to adopt vertical boilers where the peculiar circumstances indicate such as convenient and desirable. They might more often take the place of Cornish boilers, with great saving in ground-space and equal steam-raising power and safety.

Some prejudice exists unfairly against the vertical boiler. One may see lists of explosions averaged to classes of boilers, and the vertical type always heads the list. But the cause is not the verticality of construction *per se*, but the fact that it is the vertical boiler that is employed in thousands for rough contractors'

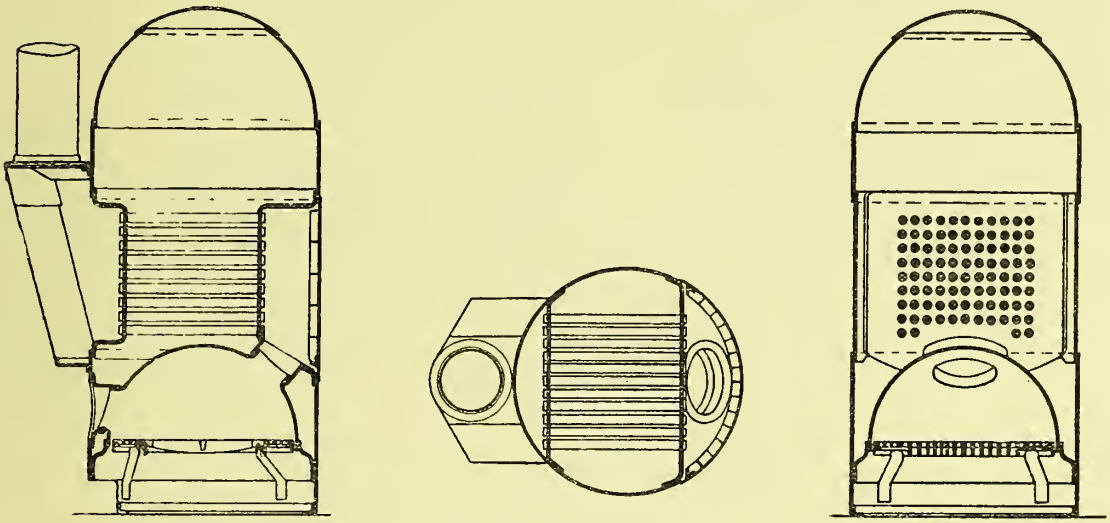


FIG. 12.—PLAN AND SECTIONS OF VERTICAL BOILER.

use, etc., having the roughest handling, little care, and the worst of feed waters. Hence, accidents happen in large percentage among the vertical boilers, to the disrepute of the class generally. Yet it is demonstrable that the vertical boiler, scientifically designed and properly constructed, is as safe as any other kind. It is true that there are many inferior types of vertical boiler, and, as a general rule, too much reliance, in design, is put in rigid staying, with the result that there is none of that measure of elasticity that is recognised as a prime condition in first-class boiler designing. It is evidently a sounder fundamental plan to arrange so that the necessary parts of the boiler are of such a nature, and so designed, as to themselves resist the stresses of high pressure, and the variation in temperature and pressures, *inter alia*—that is to say, that other necessary points are recognised to be in accordance with good practice, such as water below fire-level, etc., and

the highest class of modern mild-steel boiler construction, with its accurate machine work, and hydraulic flanging and riveting being taken for granted.

It is long known that all high-pressure steam generators suffer some deformation under such high pressures, when compared with their form when cold—i.e. as designed by the designer. The great problem in boiler design, that has become increasingly pressing with increase of working pressures, has been to meet this position. There are two ways—resist the deforming tendency and power, or allow reasonable liberty for expansion—elasticity or opportunity for some amount of breathing. A great many vertical-boiler designs include either bar or plate stays, or both, the object being positive resistance—rigidity. In the large Lancashire type of boiler, the problem has produced a tendency to favour dished ends. Without

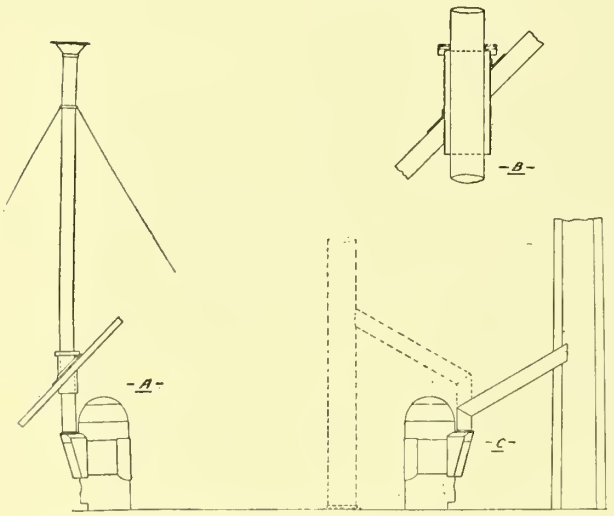


Fig. 13.—Smoke-stacks for Vertical Boilers.

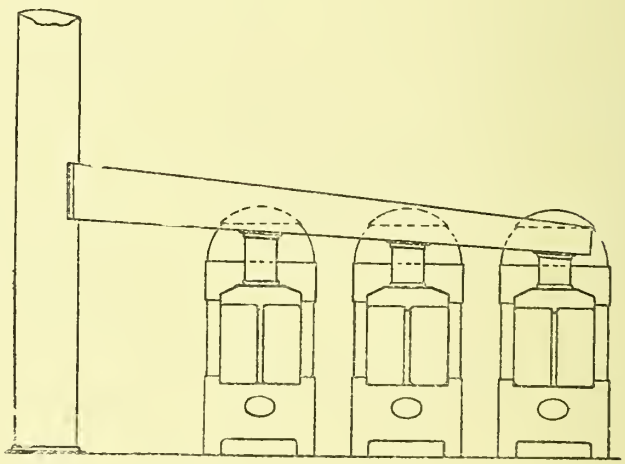


Fig. 14.—Battery of Three Vertical Boilers.

expressing any opinions as to this, it may be pointed out that a vertical dome-headed boiler is more in the nature of a dished-end shell boiler than that with flat end-plates and gusset-stays. It, after all, as will be gathered from examination of Fig. 12—representing a vertical boiler in three sectional views—much resembles the "Scotch" marine boiler, only set up in a vertical form. A great point in the design is the hemispherical, seamless furnace. The head is a true hemisphere, and stability is given by the design of integral and necessary features. Powerful heating-surface is provided by the short flue tubes; the grate surface is practically the area of the boiler's base, ensuring high evaporative duty; while the incandescence of the combustion-chamber fire-brick lining ensures smokeless fuel-burning.

The author has found this boiler in every respect excellent for small bath-house duty, and it should be equally suitable in institutional engineering, especially on those occasions where something smaller than the usual run of shell boilers is required. The point that will most interest engineers is the fixing relative to smoke-stack, and the coupling-up of boilers to work in batteries; for, as respects seating, these boilers are practically self-setting, so long as a hard, firm floor is provided. The accompanying drawings have been prepared for this purpose, and as suggestions for engineers requiring to connect and to provide shafts to vertical boilers. Fig. 13 (A) shows the usual funnel arrangement, giving excellent results in steaming, Fig. 13 (B) showing in detail the method of making good where a flue passes through a roof. Fig. 13 (C) shows the lead of a funnel, where a brick-

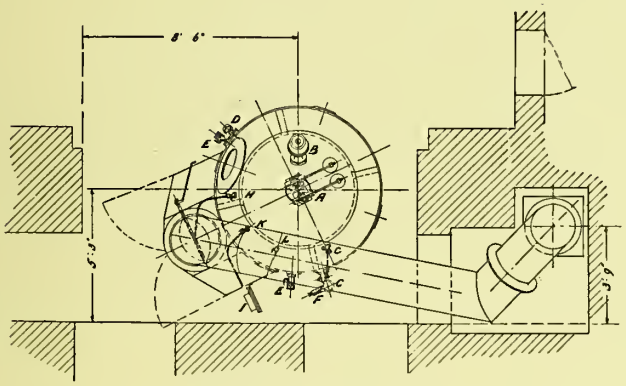


FIG. 15.—VERTICAL BOILER FOR STEAM SUPPLY TO KITCHEN: PLAN.

A, double lever safety-valve; B, stop-valve; C, combined feed check-valve and cock; D, blow-off cock; E, water gauges; F, injector; G, injector steam-valve; H, steam-jet cock; I, pressure-gauge; K, pressure-gauge cock; L, tester cock.

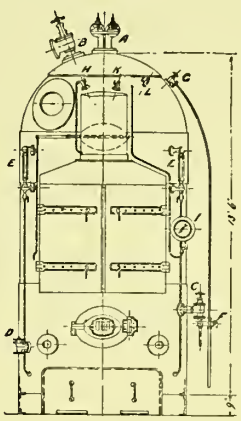


FIG. 16.—VERTICAL BOILER FOR STEAM SUPPLY TO KITCHEN: ELEVATION.

stack is used instead of an independent iron chimney: the flue-pipe can be led in any direction, but it is important that there should be as much inclination in the flue as possible, and it is *desirable* that the chimney be not used for other purposes. This is by no means necessary, however. In the Dowlais Baths the vertical boiler flue breaks into a chimney serving two large Lancashire boilers. A bend up in the shaft is advisable. Fig. 14 shows an arrangement of boilers to work in a battery, with a common uptake leading from the smoke-boxes. The uptake may lead either to an independent iron, or to a brick chimney.

Three Lancashire boilers evaporating a total of 15,000 lb. steam per hour would require, with flues, to occupy a ground area in the boiler-house of, say, 900 super. ft. Three vertical boilers, of the same steam-raising capacity, would

stand on a net space of about 170 super. ft., showing what, if necessary, can be accomplished with vertical boilers on restricted areas.

The illustrations Figs. 16 and 17 are of a vertical Cochran boiler, installed for kitchen work at the telephone power-station of the General Post Office, London. The convenience of the vertical type of boiler is shown, being here compactly stowed away practically in the front area, the flue-pipe being carried up on the face of the main wall above.

CHAPTER IV.

THE CORNISH BOILER.

The Cornish boiler is a form of steam generator to be found in large numbers in the smaller class of institutional building. A large institution, having, say, a battery of powerful Lancashires, may offshoot subsidiary buildings where the single-furnace boiler is employed. A case in point is the school of the Bethnal Green Board of Guardians at Leytonstone, the plans of the heating arrangements at which are given herewith. For the particulars from which the drawings were prepared, we are indebted to Mr. David Thomas, the clerk to the guardians. Mr. Thomas is an expert in all poor law matters, his keen interest in engineering economies being ably seconded by the efforts of the guardians' chief engineer, Mr. G. F. Broadley. Great fuel economy results have been obtained in the Bethnal Green institutions. The present diagram shows a simple piece of steam heating, cooking, etc., at the guardians' school, and is a useful illustration for a small class of institutional building.

Two Cornish boilers are installed. The duty consists of heating the dining-hall, the cooking and boiling tanks in the laundry, and the swimming-bath. There are sixteen radiators in the hall. In the kitchen are a steam oven, and three double steaming coppers. The size of main pipes are figured on the drawing. The condensation returns to a feed tank. In this tank is a coil utilising the feed-pump exhaust. The whole of the radiators are controlled by one steam trap, and have a separate condensation main. Each pair of coppers has a steam trap. and also a vapour pipe. In the basement is a calorifier supplying hot water to the kitchen, etc. A branch steam-pipe runs underground to the laundry and supplies ten boiling tanks, the end of pipe discharging condensation when steam is first turned on into a tank, otherwise the condensation passes out of the valve into a boiling tank. The heating of the swimming-bath is by injection into the water. The capacity of each boiler is about 1500 lb. of steam per hour. The whole forms a useful example of straightforward steam engineering for heating and cooking, and laundry work of an elementary kind. One boiler is always a spare.

A point is reached in reduction of the size of the Lancashire, where two

furnaces would be of impracticably small diameter, just as, inversely, a point in size of Cornish boilers is reach where two flue tubes become reasonable and necessary.

The above is a rational view of the relative position of the two types of boiler. As a matter of fact, Cornish boilers are listed by makers up to as large a size as 30 feet by 7 feet. The flue in such cases may be 3 feet 6 inches in

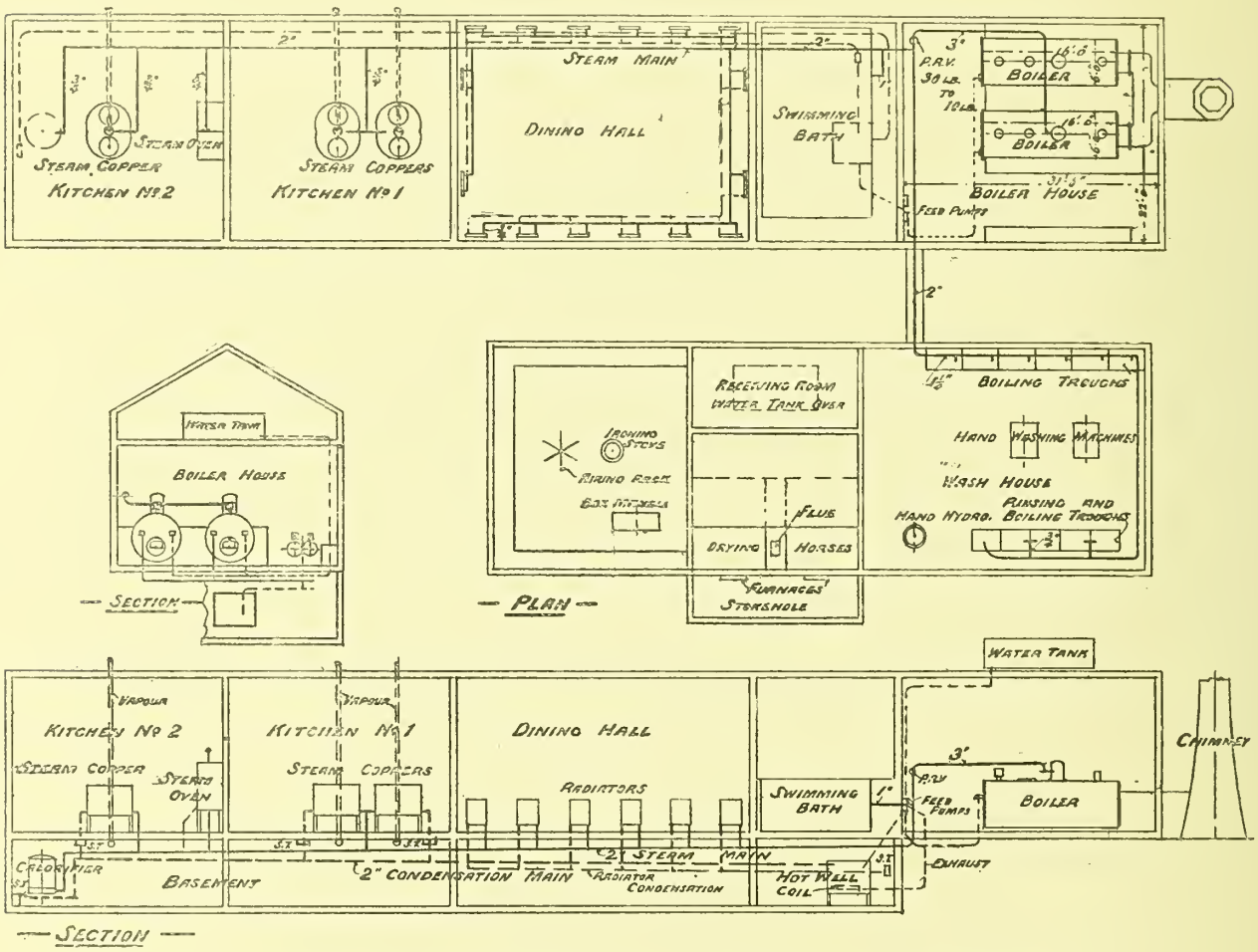


FIG. 17.—THE BETHNAL GREEN BOARD OF GUARDIANS' SCHOOL, LEYTONSTONE, E.: DIAGRAM OF STEAM HEATING.

diameter, and so lends itself to the fitting of automatic stokers. The Lancashire is made of as small a shell diameter as 5 feet 6 inches, but this only permits of a 2-foot fire-tube, practically precluding automatic furnace fittings. A fair maximum for Cornish boilers is 24 feet length of shell and 6 feet of diameter, which permits a 3 feet flue, a minimum desirable size in either the one or the other type.

The single furnace greatly simplifies the boiler, and of itself presents no objectionable feature in boiler design, for the original introduction of the twin furnace by Fairbairn was for the better combustion of the fuel. Hence, one great advantage of the Lancashire is that, in these days of stringent smoke regulations, cheaper fuel can be burned than in the single furnace. The Cornish may be said to be the prototype of internally-fired boiler, and it is probable that it will continue to be largely employed for the work of the heating engineer, whatever developments may be made in other directions; while, at the same time, for large plants few would think of putting in anything but a two-flued boiler. Bearing on this point of Cornish *v.* Lancashire boilers for any given duty, it must be considered that to greatly exceed 3 feet diameter of furnaces is not desirable, needing increased thickness of plate in a part of the boiler where such increase of thickness is particularly undesirable. Much, it is true, is nowadays done by corrugated, ribbed, or other flue connections, to ensure against collapse; but just as the engineer requiring a larger boiler unit than the largest Lancashire —which is about 9 feet diameter, or a little over—would choose the water-tube construction, so he would abandon single-flued shell design for Lancashire two-flue, when the diameter of the furnace has reached a maximum of 3 feet.

The excessively short Lancashire is not thermally efficient, such a boiler indicating an economiser as desirable. Lancashires, 14 feet long and some 5 feet 6 inches in diameter, are mere models, but are listed; and did we know beforehand that very stringent regulations were in force in the district respecting smoke, or where a bituminous coal only is available, such a boiler might be reasonable. Apart from such considerations a larger Cornish boiler is better, because giving longer traverse for the products of combustion, beside the practical convenience of a larger fire-tube. Factors, therefore, influencing this question of single or double flue shell boilers are the nature of duty, the fuel, the feed-water, the neighbourhood, the class of stoker even for careless firing, will upset the combustion, otherwise practically perfect in the skilfully-stoked Lancashire. As a rule, in practical business, it means a Lancashire for large duty and a Cornish for small.

The modern shell boiler is constructed of a carefully selected mild steel, in which the tensional strength is considered strictly with reference to ductility of the plate. All work is machine-flanged, all rivet holes drilled, all plates annealed after working, and all rivets machine-closed. Little change has been made in the shell formation generally, so far as concerns the long barrel, excepting the strengthening for modern high pressure as indicated by experience. The engineer has, however, a selection as respects end-plates, which, in a measure, still are, as they have ever been (next to furnace design) the weak point about shell boilers.

The position is to meet the conditions brought about by the behaviour of the barrel and furnace under working stresses. Fire, water and steam are, in boilers, more or less in antagonism, resulting in strains. Grooving, as the most serious result of the constant warping at the end plate, has of late sought to be remedied, or, at any rate, ameliorated by dished ends. Flat ends with the old time gussets or unstayed dished ends are the two recourses before the present day engineer.

The dished end is attractive. The engineer, however, maintains an open mind, large numbers of plain, flat ended shells being specified, in spite of the allurement of the dishing. Where the position is rather obscure, and, as it were, permanently *sub judice*, we may hazard the suggestion that dished ends in large Cornish shells are rational, inasmuch as the bellows action takes place about an axial line, at any rate on plan, whereas in the Lancashire (as in the eccentrically-disposed Cornish furnace) the stresses are asymmetrical, not only as a relative to a vertical section, but also as respects the plan. Were the Cornish boiler flue exactly axial—i.e. central down the shell—the dished end would require no special pleading for the consideration of engineers. Even in this case the construction would not be ideal, the hogging of the fire-tube being long recognised as tending to twist the boiler ends. Boiler design is throughout a compromise, and, among other practices to bring about strength with a measure of elasticity, the stopping of the gussets some way short of the flue-tubes seems to have resulted in practical success, evidenced by a satisfactory life.

It is considered a defect in Cornish boilers that the small space between the bottom of shell and the lower part of the furnace does not lend itself to effective cleaning, and for this reason a certain number of single-furnace boilers have been constructed with an eccentrically disposed fire-tube, more largely, perhaps, on the Continent, where also the dished end has been much in favour, probably as a direct descendant of the old "elephant" type boiler. To meet this difficulty in blowing-out the mud from Cornish boilers the suggestion has been made that, in place of the standard arrangement of blow-off, a long perforated pipe should be fitted, it being an observed fact that in blowing-out Cornish boilers only a part of the mud—that a little distance from the end plate—is cleared away,

Despite criticism, it remains that, for building-heating duty, and generally for institutional engineering, for relatively small maximum load, the Cornish boiler will always be a favourite, and from its simplicity and honourable record deservedly so. The details have scarcely varied since the earliest types were produced. A man-hole, steam junction-valve, a blow-off, and the usual end plate fittings, complete a thoroughly tried and practical institutional engineers' high-pressure steam generator. The selection of the best style of furnace tube, is perhaps the most important item after general sound design and construction. A powerful shell, ends up to the

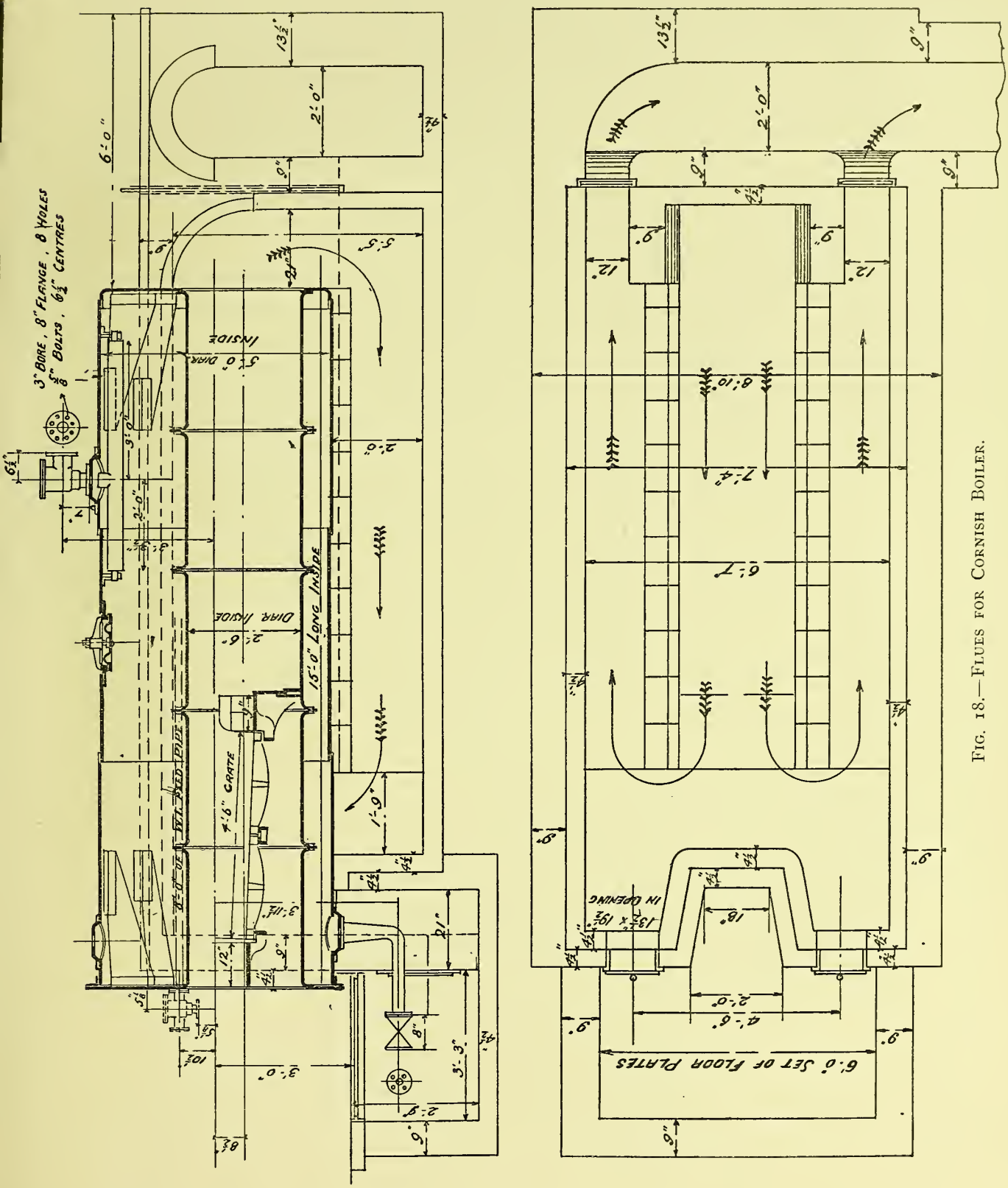


FIG. 18.—FLUES FOR CORNISH BOILER.

latest practice, and a good elastic and durable type of flue tube, are the fundamentals of Cornish, as of Lancashire, boilers. The whole preferably sits on special fire-clay boiler seatings. The flues may be built in one or two ways. If there is likely to be much mud it seems most reasonable to split the gases right and left, for as the mud will collect at the lowest point, there is, on this system, less danger of overheating plates, inasmuch as water circulation is not what it ought to or might be. It is, however, considered better for the life of the boiler that, where the feed is good, and proper cleaning performed, the discharge is first under the boiler, subsequently splitting right and left, as in Fig. 18, a setting-out plan for one of Messrs. Tinkers', Ltd., Cornish boilers. These are the main arguments as to the flues of Cornish boilers. Where Lancashire boilers are concerned the question of perfecting combustion should be considered, and this seems best effected by a primary discharge from furnaces into the lower flue. Ignoring all other points except the life of the boiler, and assuming good feed, attention and cleaning, there can be no doubt that the latter system of flue-building, either for single or double furnace boilers, is the most scientific.

It is very common to find a battery of two Cornish boilers, and one is here, as a rule, a designed (actual) spare. The meaning of this is that one boiler is, in a sense, superfluous, but this is a necessary state of things where only two units comprise the whole.

The moderate pressures customary and to be recommended in institutional engineering make the Cornish boiler highly suited to the duty. High pressure is eliminating, to a great extent, shell boilers in power-station work, but it is not that there is defect in the type as such, where moderate pressure is used, but that the design and construction of the water-tube is better fitted for the high pressure found desirable in such places. Both in theory and practice the great defect of plain, shell boilers is want of circulation. As a result, their elasticity in steam generation is much inferior to the water tube. Galloway tubes are said to, and plainly must, greatly promote circulation, and in any case, given careful steam raising from all cold, and a regular duty (even load), the Cornish boiler has long proved a most satisfactory appliance. The fact that another class of steam generator is making great strides for special duty, in no way suggests that the simple Cornish type should be deemed old-fashioned. In its proper sphere it seems yet to be without a serious competitor.

CHAPTER V.

LANCASHIRE BOILERS.

On October 17, 1907, Mr. John Burns, as President of the Local Government Board, appointed a committee to inquire and report on machinery and engineering staffs in poor law institutions. The Committee consisted of Messrs. Arthur B. Lowry, B. T. Kitchin, F.R.I.B.A., and H. R. Hooper, M.Inst.C.E., with Mr. I. G. Gibbon as secretary. The report (C.D. 4502) was made under date January 9, 1909, and is a document that should be in the hands of all engineers and architects, and others interested in institutional engineering. The whole minutes of evidence are a mass of valuable opinion from experts.

Among the witnesses were Mr. W. T. Hatch, Whit.Sc., M.Inst.C.E., Engineer-in-Chief to the Metropolitan Asylums Board, who said: "Where space is available, the Lancashire or Cornish type of boiler is undoubtedly the most satisfactory;" and Mr. Clifford Smith, M.Inst.C.E., Engineer to the Asylums Committee of the London County Council, who concurred: "The Lancashire boilers, with large steam storage spaces, are the best fitted for the work under consideration." From engineers of such wide and special experience this testimony is conclusive as to the value of the double-furnace shell boiler for institutional work generally.

The modern Lancashire is a construction of ductile steel plate. All late improvements have been directed towards lengthening the life of the boiler by design calculated to negative the effect of stresses set up by the pressures now carried, their variation and alternation. All work is machine work, all rivet holes are drilled. The remarks before made as to dish-ended Cornish boilers apply much to the Lancashire, when the question of type of ends is considered; but there is this difference—that the furnace of the Cornish boiler—unless purposely eccentric—is central and axially disposed in the shell, so that, as before observed, this makes in such boilers the dishing theory more attractive. In the case of the Lancashire, if we consider the vertical and horizontal views of such, we notice that the symmetrical balance of parts is supplanted by one-sided effects at all points. The general design of the single-furnace boiler gives more even distribution of stresses round about the ends of the fire tubes, the contraction and expansion of

the flue give equal effect all round, and the greatest bending movement occurs near the shell end. If we are to regard the dished end Cornish boiler as having relatively constant length of shell and varying tube length, the movements of the connecting flue plates have equal value at equal distances from the boiler axis; whereas, in the case of the Lancashire, the stresses in detail are greatly complicated by asymmetrical disposition of the furnaces.

There are one or two great industries where the factor of the specialist manufacturers' accumulated experience and repute more or less completely override the weight of opinions of independent theorist engineers. Among these must be classed boiler-making. As a practical deduction, where the consulting engineer has to decide on a type of steam generater—its construction—if he finds great and respected firms working either on one or the other main principle of design, or on both systems indifferently, he may rest assured that his time expended on the main principles involved may, in practical business, be considered as waste of energy. Hence, on an apparently vexed question, one might conclude that he who adopts flat-ended boilers does well, and whoso chooses dished ends does well also. We have ventured these remarks because the point is one where the engineer may easily get "in two minds," and no formula will help him or relieve him of the necessity for exercising his own power of reasoning.

In institutional work one does not find model Lancashires—i.e. the extremely small sizes listed by makers. Their place is taken by the Cornish boiler—30-h.p., based on the old 30 lb. steam per hour for boiler-makers' horse-power, seems to be a good division line, where, in place of single furnace of 3 feet diameter, smaller flues of from 2 feet 3 inches are substituted; but the duty and special circumstances need to be considered, and especially the fuel contemplated.

The advantages of the Cornish in such comparison of determining size is longer furnace-flue and longer total flue length, for the Lancashire boiler may be regarded as having one furnace flue, the equivalent of the two in the two-flue types. The short Lancashire is powerful, but of inferior economy, solely on account of the cutting-down of flues, and such plainly indicates the economiser as an adjunct.

The small Lancashire may be more smokeless. It is not necessarily for that reason more efficient, black smoke being not inconsistent with good thermal results. The larger furnace, moreover, assists combustion. Given good steam coal, there is no reason why two flues should be employed until the one flue becomes of an out size. Fairbairn's object in the invention of the Lancashire boiler referred solely to matters of combustion, there being no magic in two furnaces, which become an unnecessary complication if all can be accomplished with one.

A long shell—as compared with the cut-down length of boiler—enables to be conveniently provided a high or low water indicator or alarm, a useful and almost

universal addition for boilers for public or institutional engineers, making the ordinary seatings on the boiler a safety valve, steam junction valve, high or low water valve, and a manhole, the blow-off cock, and end-plate fittings as ordinarily, with feed arrangements for both pump and injector as stand-by. An old practice in work of this class was to couple up the units forming a battery of boilers by short straight steam connections, with either packed expansion-joints or expansion bends ; whereas the modern arrangement, especially where the ring-main system is adopted, increases slightly the length of piping, but makes the mere disposition of such auto-elastic—i.e. not requiring special arrangements for expansion. The ring system is now generally adopted in large power-houses, and is just as excellent and applicable to the relatively small boiler plant of an extensive institution.

As with the Cornish, the brick flues of Lancashire boilers may be arranged on one of two plans. Fairbairn's patent specification shows two side flues only, and one is inclined to give careful attention to all details of proposals by original inventors ; but the "mid feather" needful under this system of setting a shell boiler has been found to be injurious, owing to dampness corroding the plates. It must, therefore, be considered that, although the modern Lancashire boiler remains much as originally proposed by its inventor, later efforts have produced a better method of flue arrangement. The practice now most usual is to take the gases first into the lower flue. The object is to maintain a more equable distribution of heat, and to lessen the irregular stressing of plates. There can be little doubt that for the plain Lancashire boiler the plan is good. Messrs. Galloways split the gases, relying on their special, coned cross-tubes for circulation.

A writer on boiler-setting has remarked that "there is little to choose in the systems," and it is possible that with bad water there are advantages in first sending the gases through the side flues, reducing the heat below the bottom plates where mud is likely to collect. Apart from this, the experience of engineers appears to favour the reverse arrangement.

In planning an institution boiler-house it is advantageous first to set up a cross-section giving the centre distances of boilers, and also the stack. This latter can be moved about in planning by providing suitable horizontal flue, but otherwise the completed boilers and their flues form a base upon which other engineering features are set out. In all work of this nature it is, therefore, always necessary to determine first the maximum demand for steam, and range other engineering department features in harmony with the boiler-house, which will depend on the size and number of boilers.

To arrange a battery of three or more Lancashire boilers where space is unlimited is an easy matter. Difficulties have to be overcome by the planner in a crowded town site, where every foot of space available must be utilised. The

accompanying drawings refer to the work carried out at St. Thomas's Hospital in connection with the centralisation of the boiler plant. The original arrangement for heating and hot-water supply at this institution consisted of Cornish boilers, a battery at each block. The alterations comprise the addition of two powerful Lancashire boilers. Three of the Cornish boilers have been retained, and the remainder have been removed. A suitable central block having been selected for the new boilers, the Cornish boilers were retained and connected up. The present

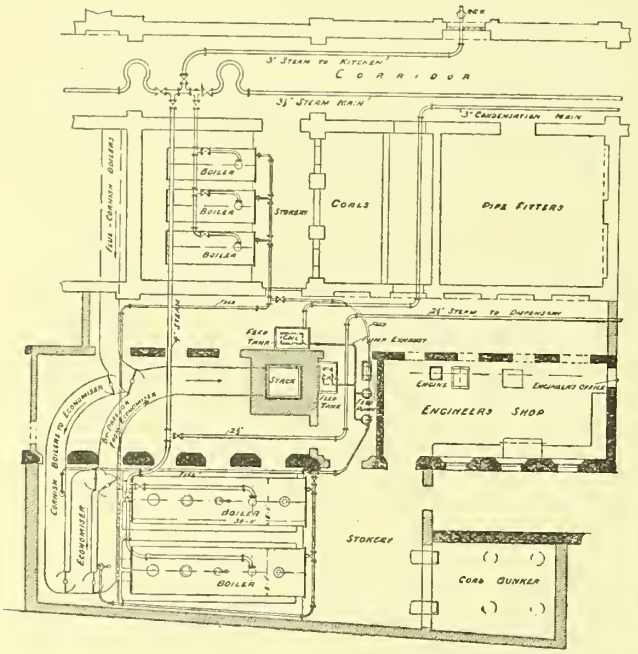


FIG. 19.—ST. THOMAS'S HOSPITAL, LONDON: PLAN OF BOILER-HOUSE.

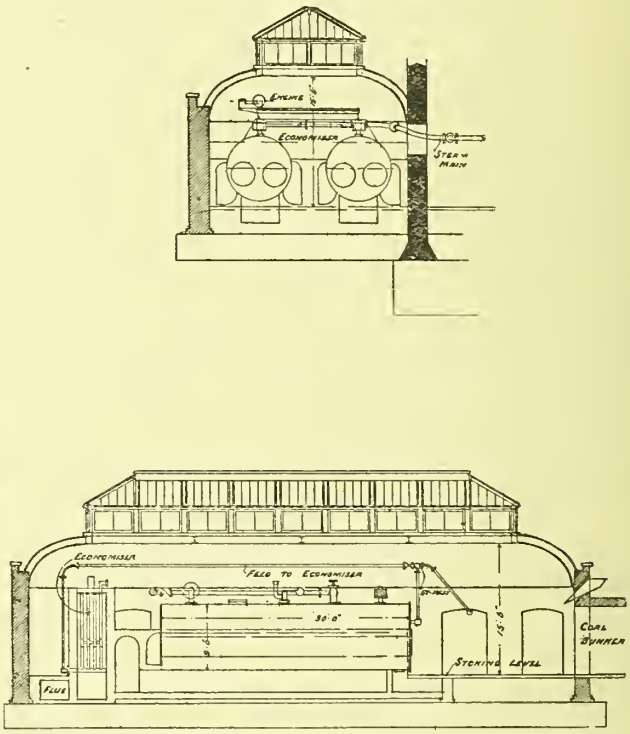


FIG. 20.—ST. THOMAS'S HOSPITAL, LONDON: SECTIONS OF NEW BOILERH-OUSE.

steam-raising equipment consists of two Lancashires of an evaporative power of 6000 lb., and three Cornish of about 2000 lb., or in all 18,000 lb. steam per hour.

Figs. 19, 20 and 21 show the arrangement as carried out from the plans of the architect, Mr. Percivall Currey. The drawings also include the new chimney-stack which Mr. Currey arranged in an angle of the building, passing through several floors, as shown. The construction adopted will be usefully suggestive to those faced with similar problems. St. Thomas's Hospital stands on ten feet of solid concrete over the whole site of the buildings. On this foundation the chimney stands. It was economically built, the walls being formed partly by the

existing old walls, as indicated. The whole is built in brick, with stone dressings, a fire-brick lining and air-space, as drawn. The chimney has shown no sign of crack, and the method of construction will be a useful illustration for those connected with city building-engineering, where an isolated stack is seldom practicable.

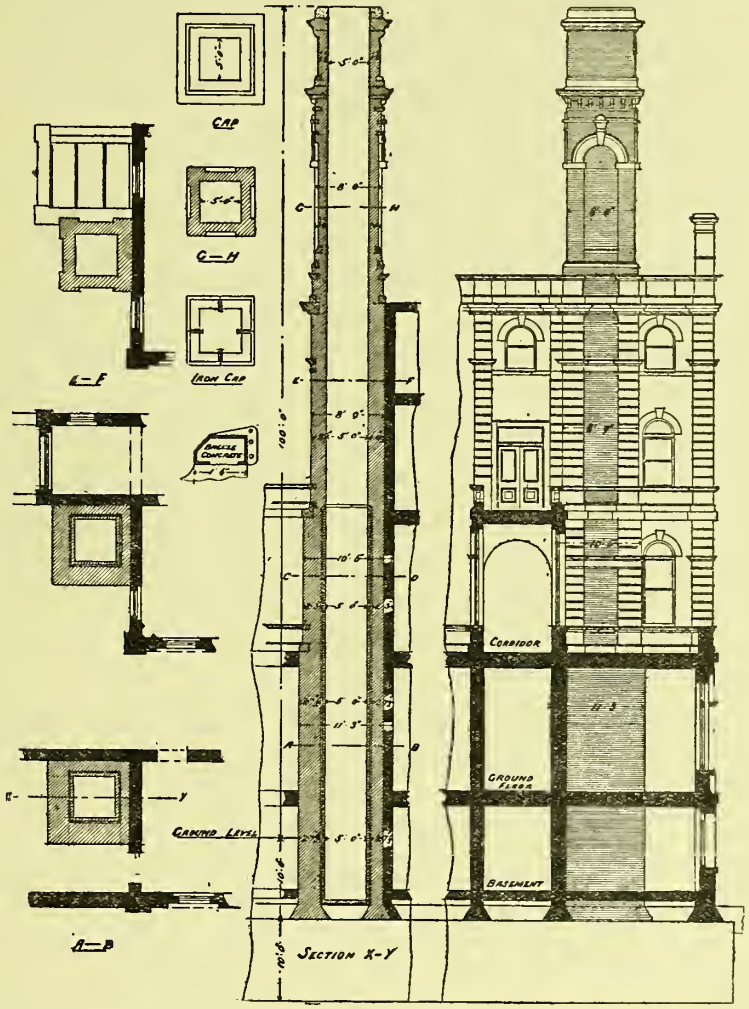


FIG. 21.—ST. THOMAS'S HOSPITAL, LONDON: PLANS, SECTIONS, AND ELEVATION OF NEW CHIMNEY.

The plan shows the flues and by-passes, with an arrangement whereby the Cornish boilers may be coupled with economiser. The boiler main-pipes connect to a $3\frac{1}{2}$-inch main in the basement corridor. The calorifier arrangements at the hospital consist of a building-heating calorifier, and a calorifier and storage tank for baths, etc., for each block.

The boiler-house is very light and well-ventilated, in marked contrast to so many London boiler-houses in institutions. It was constructed in the space between the hospital and the Lambeth Palace-road, and has a roomy lantern-light with ample opening sashes ; the coal bunker has both coal-plates and hoppers. Each boiler is fitted with dead-weight safety valve, steam junction valve, high and low water alarm, with combined lever safety valve and circulator.

As the hospital takes current from the electrical companies, the sole duty of the boilers is heating and hot-water supply. The drawings give details of steam main connections and stop valves.

The adoption of high pressure boilers results in the institutional boiler-house differing but little in general arrangement from an ordinary boiler-house for commercial or power purposes. The divergence, if any, is in the way of arrangement with respect to special features of building-heating work ; otherwise details in and around steam boilers must necessarily bear some general resemblance, whatever may be the duty. For example, in any business of steam making and supply, it is of paramount importance to economise the steam generated. Every foot run of steam main saved is not only economy in the first cost, but in running expenses, since, however thoroughly the protection against cooling, some condensation occurs and is constant for unit of length by diameter, under conditions ; which latter alone are variable. The losses that attended the old custom of manifold water heaters were in this way very great.

A calorifier chamber cannot be too closely associated with the boiler-house, at least in theory, nor to the engines when exhaust is used for heating, so that the boilers and calorifiers will mass on plan into a more or less compact group. From the boiler headers, a main and branches will run to the engine and a branch to the calorifiers, all in approved and usual steam practice, with very carefully-arranged stop-valves and by-passes for shutting off this and that for repairs, and for putting into work one or another spare appliance. In the institutional boiler-house all ordinary rules for boiler fixing and fitting will apply, as, for example, in feed and feed pumps ; and where so much heating is required, these veritable steam-eaters will not seem so objectionable as they usually appear on an examination of their thermal efficiency. The exhaust can be run to heaters for feed or otherwise, many varied arrangements being possible according to special exigencies, and as to whether economisers are to be installed.

If no oil separators are fitted, any hot oily water usually runs to waste ; it can, however, at least be made to give up its heat to the cold feed water by very simple devices of tube coils passing through tanks.

The whole arrangement of engine-house, boiler-house and calorifier chamber needs to be made primarily to the conservation of heat, in establishments burning

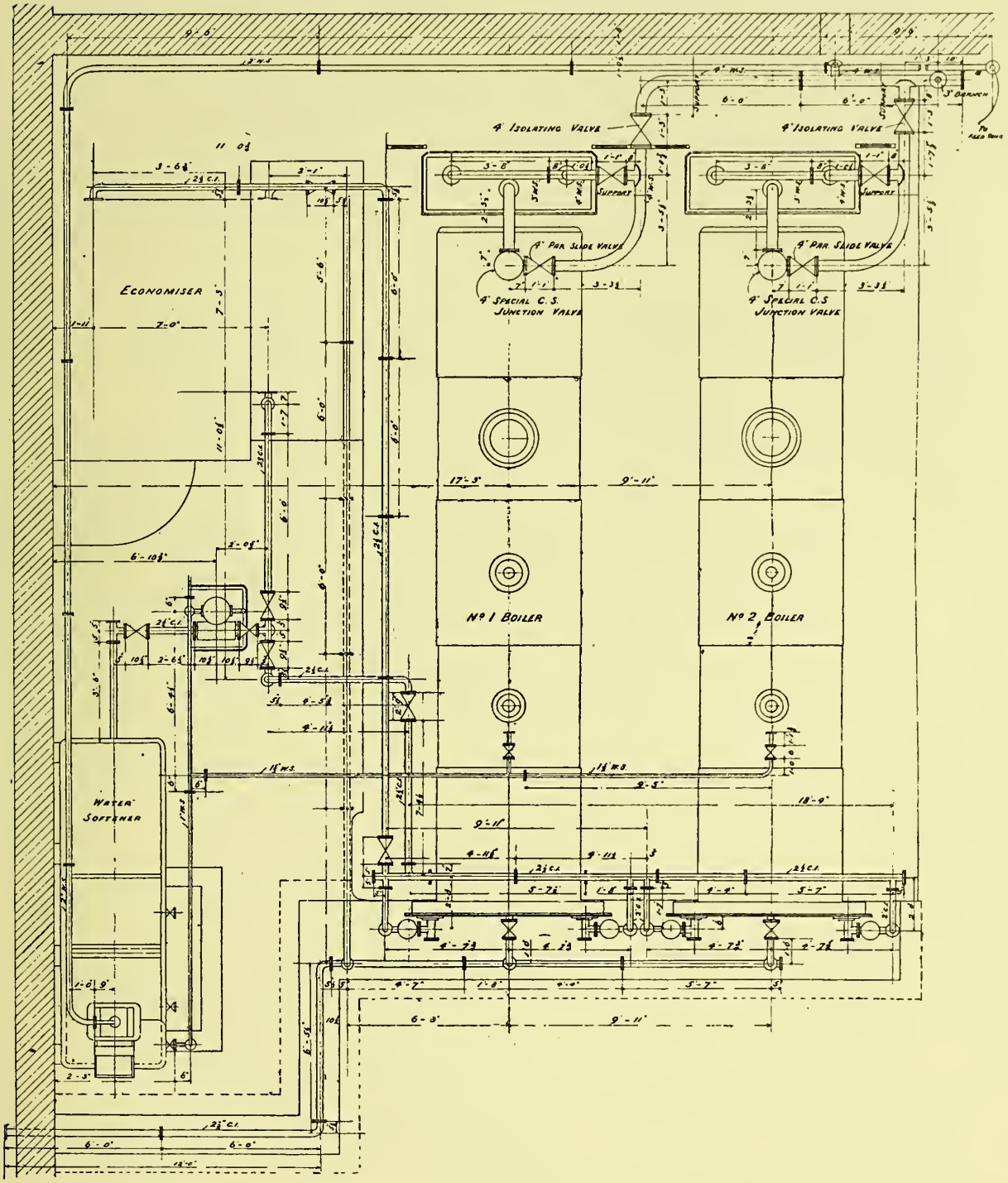


Fig. 22.—General Arrangement in Boiler-house of Lancashire Boilers, Superheater, Economiser, Feed Pump, Feed Tank, and Water Softener, with all necessary Piping and Valves: Plan.

coal by the thousands of pounds' worth annually, and it is on this account well to bring up a laundry as centrally as possible—combine it practically with the central engineers' block of buildings. By so doing the exhaust of any steam-engine for laundry machinery may go directly to calorifiers or to other heaters. Every pound of water of condensation should be returned to a hot-well. To eliminate steam traps and drains as far as possible is a great thing in this class of steam engineering, and here, it may be observed, is a great advantage in hot-water heating *viâ* calorifiers, as against direct steam—the absence of the need for manifold wasteful steam traps.

Small economies are here important, the sum total of apparently small wastes may be large in establishments evaporating over 100,000 lb. steam daily; or as at the Government Hospital for the Insane at Washington, burning yearly 20,000 tons of bituminous coal besides a considerable quantity of anthracite.

For steam mains and branches of so small a diameter as here considered, modern ideas possibly tend towards cold-drawn weldless tubing. The engineer has, perhaps, too long lingered over the lap-welded steam pipe. Stop-valves, inasmuch as they will be in most cases either fully on or fully off, should have full ways. A good indication of the thought bestowed on engineering of this class is the run of the piping, and examples of how not to arrange these details are to be notably found in such buildings as the older public baths and washhouses; but the deficiencies in this variety of plan and design may be observed in even large power-houses—an inextricable medley of pipes, traps and drains, and even high-tension cables, notably in those cases where the leads drop down from generators to cross below driving floor level on their way to the bus-bars. In these days of cheap tracing-paper and sun-printing a system of separate plans for separate services could be followed with advantage. In practice, in electrical work, high tension cables—if present—should be in proper cable-ways, isolated as far as possible, and as concerns steam and water pipes. Only forethought and careful planning of details—scientific lay-out—can ensure this.

Fig. 22 is a plan, Fig. 23, an elevation, of two Lancashire boilers as installed at the Peterborough Waterworks; the plan was prepared by Messrs. Galloways, Ltd., who made the boilers and carried out the whole installation.

The boilers are plain Lancashires, 26 ft. by 7 ft., the primary flue being the lowest—two dampers being necessarily fitted. As the products of combustion emerge from the furnace tubes they enter the superheating chambers, subsequently going through an economiser unless diverted to the by-pass. The plans show every pipe length and valve for saturated or superheated steam supply, for feed, and for blow-off, etc. The cast-iron feed-tank is fixed overhead. The feed may be either direct or through economisers. A water softener is supplied, operated

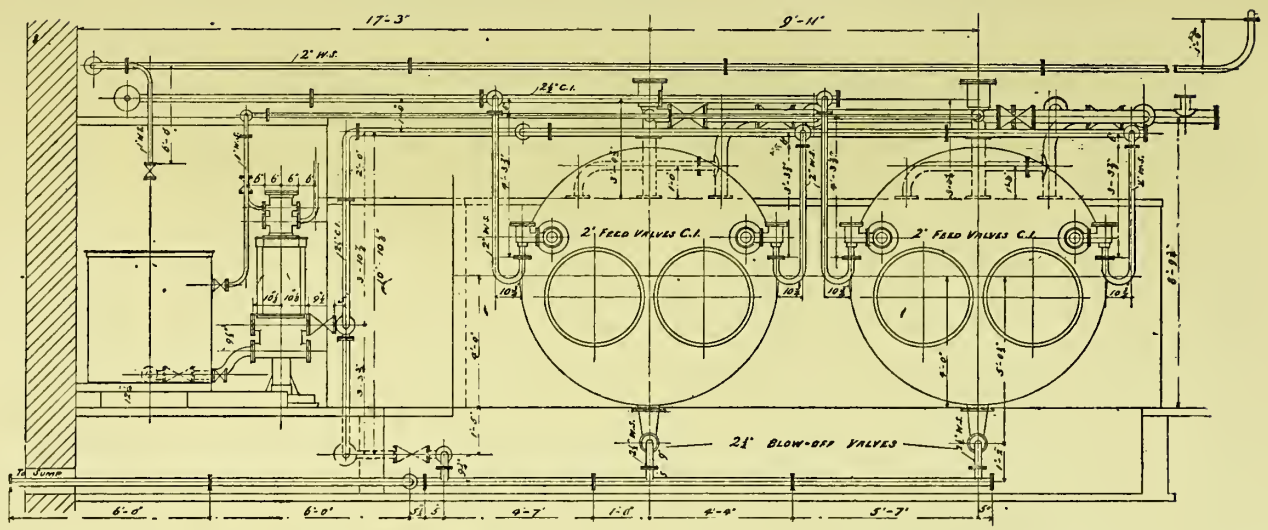


FIG. 23.—GENERAL ARRANGEMENT IN BOILER-HOUSE OF LANCASHIRE BOILERS, SUPERHEATER, ECONOMISER, FEED PUMP, FEED TANK, AND WATER SOFTENER, WITH ALL NECESSARY PIPING AND VALVES: ELEVATION.

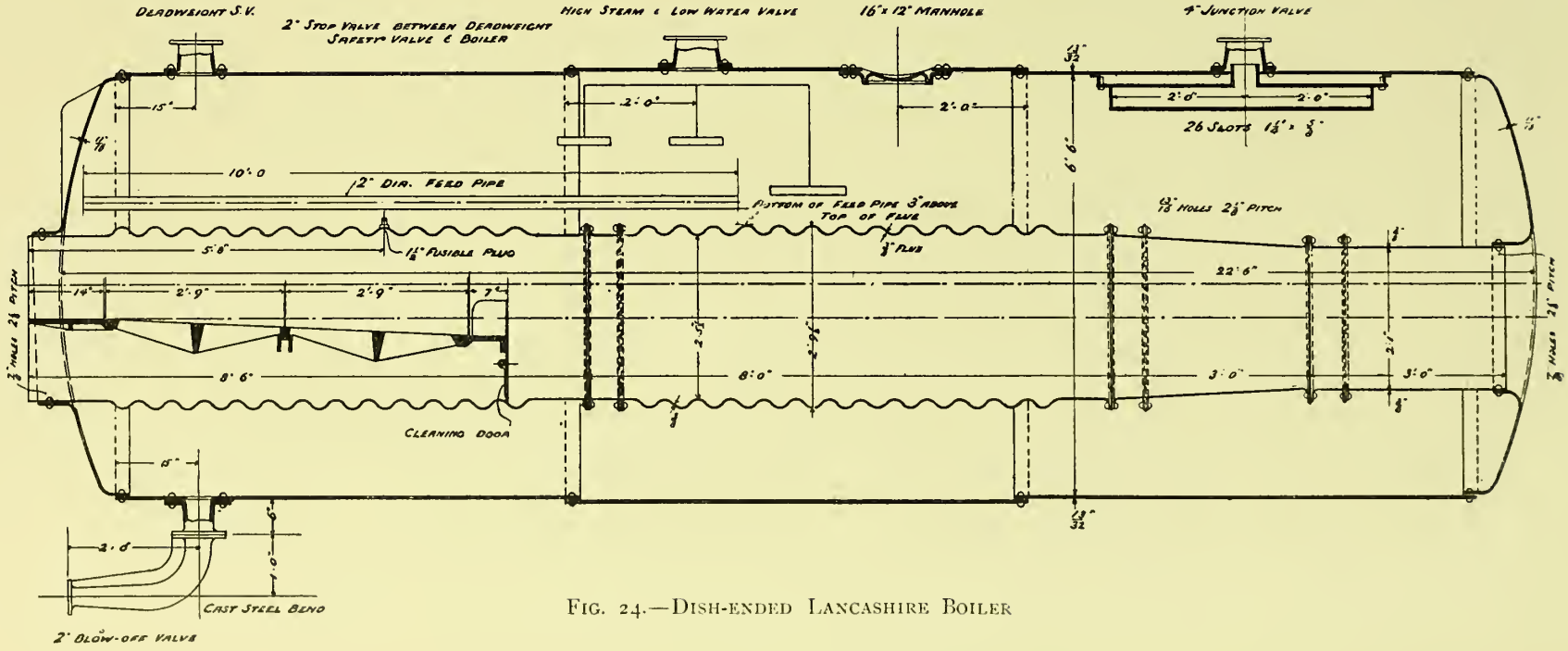


FIG. 24.—DISH-ENDED LANCASHIRE BOILER

by live steam, the water being chemically treated and filtered, throwing down, at 180 to 212° F., any impurities. In the ordinary way the feed is taken from the softener tank.

The superheating of steam for building-heating work may seem important to the unitiated, and useless in the view of the heating expert. Some views on the point are put forward in Chapter VIII.

The superheating details at the Peterborough Waterworks in no way lessen the value of Messrs. Galloways' plans as an example of boiler-house pipe work, interesting to institutional engineers and engineering students.

Fig. 24 shows a fine dish-ended Lancashire boiler, as made by Messrs. John Thompson, of Wolverhampton, for the Solihull Workhouse, near Birmingham. The firm have done much to popularise the dish-ended system of construction.

CHAPTER VI.

THE DRY-BACK BOILER.

A considerable demand for steam may exist with but scanty accommodation in the way of a boiler-house. The most suitable class of boiler would be, say, the ordinary Lancashire, but a battery of such cannot be packed into the available space. Under such conditions a favourite recourse is the multitubular, horizontal, shell boiler—the so-called "dry-back." This will give the same amount of steam as a Lancashire that would take up twice the area, or thereabout. It is a good steam raiser, and quite suitable for institutional engineers' work. A recent good example is the range of dry-backs in the boiler-house of the Great Eastern Railway Company's Stratford power-house.

There is not much scope for variety of detail in the Cornish and Lancashire boilers by different makers; but the dry-back lends itself to some considerable variation, especially as respects flue arrangements. Essentially, this useful type of steam generator consists of a cylindrical shell, with either one or two furnace flues, and a number of small tubes running, like the flue tubes proper, from end to end of the boiler. The shell construction system follows, generally, the Cornish and Lancashire models, but does not so well lend itself to dished end-plates. As a rule, the boiler has two furnaces, on the Lancashire system, and may be constructed either for complete brick setting, or self-contained with iron smoke-boxes, etc. Large heating surface results for the cubic space occupied: the combustion results are at least as good as in the Lancashire; steam is rapidly raised, and greater elasticity is obtained than with plain shell boilers, while the whole may be readily cleaned. For town institutions, and for hotels, office blocks, etc., where space is valuable, the dry-back is a most serviceable boiler.

In construction, in accordance with modern practice, the shell plates are in one length, with strong longitudinal seams, all flanged and all riveted by machinery wherever possible, and other details in accordance with latest ideas, the tubes being cold-drawn weldless steel, expanded into end-plates. As a rule, however, a certain number of tubes are screwed and beaded over, or stay-bolts are provided assisting to tie in the boiler, all much in accordance with Scotch marine boiler practice; in fact, the whole really constitutes a variety of such, with furnaces only at one end

Combustion is greatly assisted by the brick-lined chamber at the back, which becomes incandescent, in a measure, during working. The construction is simple and straightforward, and steaming results satisfactory either for lighting or building heating duty, or for a combination of such.

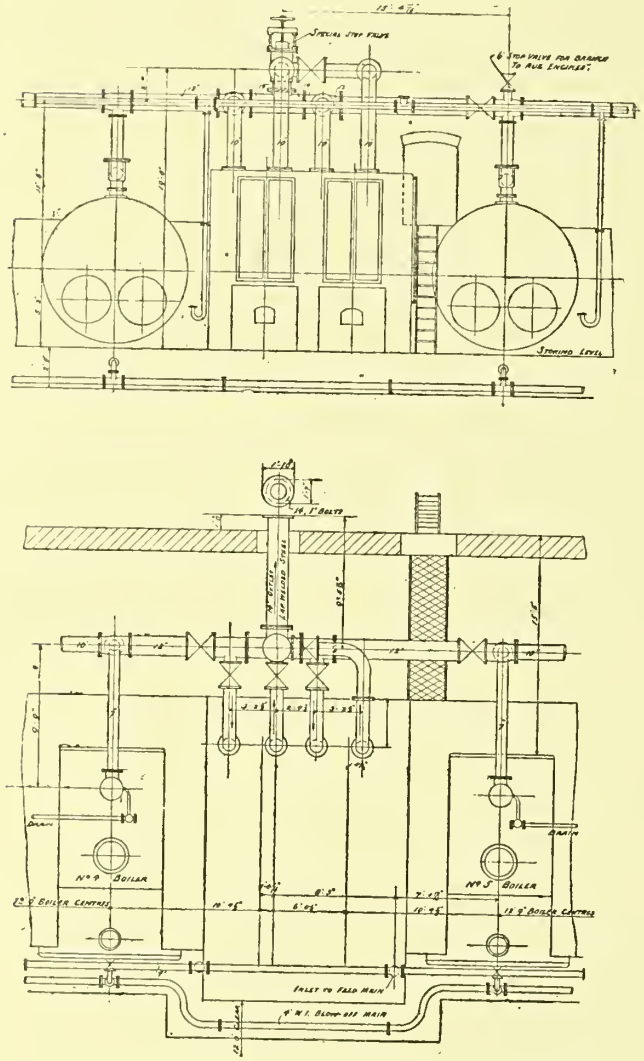


FIG. 25.—GENERAL ARRANGEMENT OF MAIN STEAM, FEED AND BLOW-OFF PIPES FOR BATTERY OF DRY-BACK BOILERS: PLAN AND ELEVATION.

The shell diameter of Lancashire and twin-furnace dry-backs for similar power will be nearly alike. The space-saving affects length. Allowing 9 feet between coal store wall and the front end of a 30-ft. Lancashire boiler, and a main flue for the whole battery at the back end, which would be tight against another wall, the width of such a boiler-house cannot be less than 47 feet, whereas 30 feet would be more than ample to house the dry-back under similar conditions.

The shortness of these boilers lessens space at top for mounting, etc. If an anti-priming pipe is provided and allowance made for manhole and for a steam connection and a safety-valve, on one and the same seating, there is no room for a separate high-and-low water indicator, which is a most useful and desirable fitting in institutional engineering. It is, however, possible to combine such with a safety-valve device.

The most usual style of constructing this useful type of boiler is with integral smoke-boxes at front end. Apart from these additions the boiler resembles a short, dumpty, ordinary shell, Cornish or Lancashire, according to whether one or two furnaces are provided, and excepting that certain stay-bolt ends and nuts generally appear on the upper part of the end plate. These smoke-boxes, provided with sweeping doors, formed of iron or steel plate, receive the gases on

their emerging from the small fire-tubes. The presence of these smoke-boxes generally makes it necessary that water-gauges and the feed-check valves also project out on short lengths of tube. With furnaces, doors, and mounting, etc., the boiler is thus complete, and requires setting as an ordinary shell boiler, modified in detail according to the ideas of the setter, but, in any case, the furnace gases at once return (from the fire tubes) through the small tubes. The outlet from the smoke-boxes is at the bottom of the boxes. These require connecting to brick flues. One way is to construct side flues, a side and bottom flue forming one hot-gas chamber, which can pass out towards the chimney. On this plan the utmost is made of the heat of combustion. In place of this they may drop down to a horizontal flue, running away from the front end of boiler to a stack ; and so in several minor modifications, according to the idea of the designer of the setting, a damper being provided at a convenient position, short of the vertical chimney shaft, and the usual drained blow-off valve pit is arranged.

In self-contained designs, the boiler stands on cast-iron bearers, an iron, brick-lined, combustion chamber is built at the back, and the smoke-box gathers over in sheet-iron, and connects by a flue pipe ; and so in one or two variations in detail arrangement. The type of boiler, therefore, well lends itself to cramped and awkward boiler-house sites, as may be found in city institutions and other buildings, such as bath-houses and hotels. These boilers are constructed for the highest working pressure suitable in institutional and like engineering work.

Fig. 25 illustrates the installation of, and pipe work about, a battery of dry-backs, made by Messrs. Davey, Paxman and Co., Limited, of Colchester. The boilers, two of which are illustrated, are installed in Calcutta. The whole battery consists of ten boilers, 9 feet 9 inches by 15 feet 6 inches, with independently-fired superheater arranged between boilers Nos. 4 and 5. The plans show the details for saturated or superheated supply and the feed arrangements. It should be noted, that the steam pipes are drained at the junction valve-box, a main drainage pipe leading to the steam traps. The drawing is a useful example of pipe work about a type of boiler in which Messrs. Davey, Paxman and Co. have long specialised. No economiser is provided, it being found that the low temperature of the gases—about 500° Fahr. at the damper leading to main flue—renders such an apparatus superfluous when natural draught is used, a point showing a further advantage of the dry-back where space for boilers is restricted.

CHAPTER VII.

THE WATER-TUBE BOILER FOR INSTITUTIONS.

For large institutions, for duty comprising a really heavy lighting load, for large hotels, and for many miscellaneous purposes in institutional engineering, serious consideration should be given to the claims of the water-tube boiler. A steam-generator so immensely popular with electrical engineers cannot be ignored in institution work, on such occasions as its peculiar advantages are indicated as likely to fulfil requirements.

Among these advantages it is advanced that the thin tubes admit of rapid heat-transference; that riveted joints are removed from the action of the fire; that water circulation is thorough and effective; that it has superior safety; is accessible for cleaning; allows a maximum of fire area; and that it is an "elastic" steam-generator. Against this the objection is frequently urged that the water tube construction requires an undeniable feed and superior care in those superintending, working and cleaning the boiler. It seems to be generally admitted that, this efficient care in supervision and handling being guaranteed, no valid objection can be raised to the more general installation of the water-tube boiler in buildings for public or quasi-public heating, lighting, or other duties; that, in fact, it is quite well adapted, on its merits, for use in public and private institutions and hotels.

One great advantage in the water-tube construction is the ready adaptability of the automatic furnace, which appliance has been proved to permit the combustion of low-grade and bituminous fuel, efficiently, and without smoke. It is not so easy to produce an automatic stoking device that shall be adaptable to ordinary shell boilers; and, in any case, such require a flue diameter of a certain minimum to ensure successful adaptation of existing appliances.

The fundamental idea in the water-tube is based on the theory that the water in steam-boilers requires to circulate freely, and that such circulation shall be by definite route. Most, if not all, types of ordinary boiler are assumed to be somewhat deficient in this matter of water circulation, and many alterations have been made at different times to improve matters in such types. It is obvious that the more quickly the steam formed can disengage itself, so to speak, from the

water, the more rapid the generation and accumulation at pressure in the steam space. Great numbers of varied type, and numbers of experiments, have been directed to this point of water circulation and steam freeing. For variable load boilers, as required in large electrical generating stations, such properties make for elasticity in response to sudden variations in demand for steam, hence the very great impetus to water-tube boiler adoption in large power-houses. The essential difference between the shell and water-tube boiler is, that while one has great thermal storage, both in steam and water, and therefore a great stock of potential energy at any given moment, the water-tube has great power for *producing* at short notice a large supply of such energy. The distinction requires to be observed. In the one case is a reserve of power, in the other a margin of actual power production. The elasticity of the Lancashire boiler is the elasticity (as it were) of the hydraulic accumulator, and the elasticity of the water-tube that of an engine working within its limits of power—below, that is to say, its capabilities.

As respects, therefore, the adoption of the water-tube system of boiler construction in buildings for institutional purposes, with the miscellaneous load comprised of heating, lighting, laundry and cooking, we need to inquire whether necessity exists for this great reserve of energy, as distinct from a reserve of power-storage. The distinction may seem a fine one, but is in fact quite clear and definite. The cause is the rapid heat-transference as contrasted to comparatively slow action. The water-tube may be steaming freely under load in an hour and a half from all cold. Such a result would be impossible in a large shell boiler, where great caution is needed in this respect, in order that the general heating up is accomplished at a rate that will avoid local stresses.

Sudden alternations of clear and foggy atmospheric conditions are the main cause of sudden variations as recorded by switchboard instruments at power-stations. Such conditions have their exact counterpart in the private power-house of the institution; but the total is small, where it is great in a large electrical supply company. Moreover, the sudden and abnormal peak in the institution or hotel, etc., is at its greatest a small addition only to the total load represented by supply to various departments for various purposes. In institutional engineering a sudden demand for a considerable increase of steam would be met by opening up boilers normally under easy steaming, and the ordinary institutional shell boiler would be so out of proportion to the relatively insignificant lighting load, even at its maximum, that the recourse would meet the position effectively and entirely.

The consideration made may suffice to suggest that, if water-tube boilers are desirable in institutions, it cannot be primarily for the same reason that such find precedence more and more with electrical engineers, that is, those in charge of

power-stations. It is the ready response to control acts performed in the stokery that makes the water-tube so eminently satisfactory to electrical engineers. Where a sensitive horse will respond to a light flick of the whip, a thick-skinned animal would need considerable belabouring before he woke up to the idea that some-

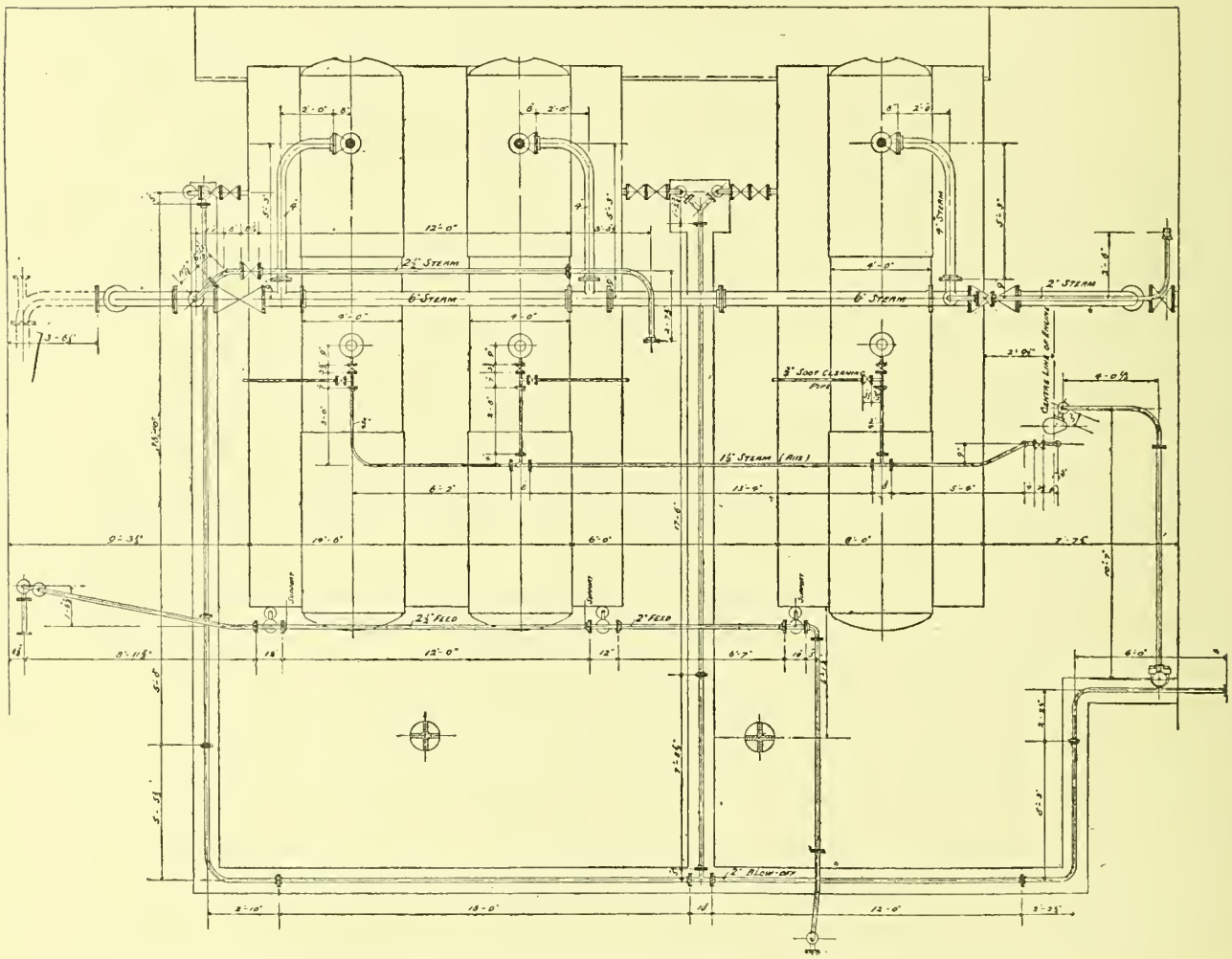


FIG. 26.—STEAM-PIPES, FEED AND BLOW-OFF FOR THREE WATER-TUBE BOILERS: PLAN.

thing was to the fore; and this comparative analogy may not, perhaps, unhappily illustrate the difference between the sensitive water-tube, and the stolid shell, boiler.

The known and easily predetermined load in institutional engineering indicates that this extremely sensitive agent for steam production is not required in, say, a hospital or asylum that has no electric lighting provision. Hence, in most cases, the simplicity of the shell boiler ensures its adoption. And the slower heat-

transference is accepted as a necessary accompaniment of this simplicity of design and construction.

On the score of safety, for high pressures, the water-tube system of construction stands high. The bursting of a tube is a very small matter compared with rupture of large diameter shells. Such an event may mean nothing beyond inconvenience: that is, no actual danger and little actual damage. Again, the steam drum can here be made of the strongest form, the dished ends of equal curve round the central axis permitting the theory to be carried out, and in an

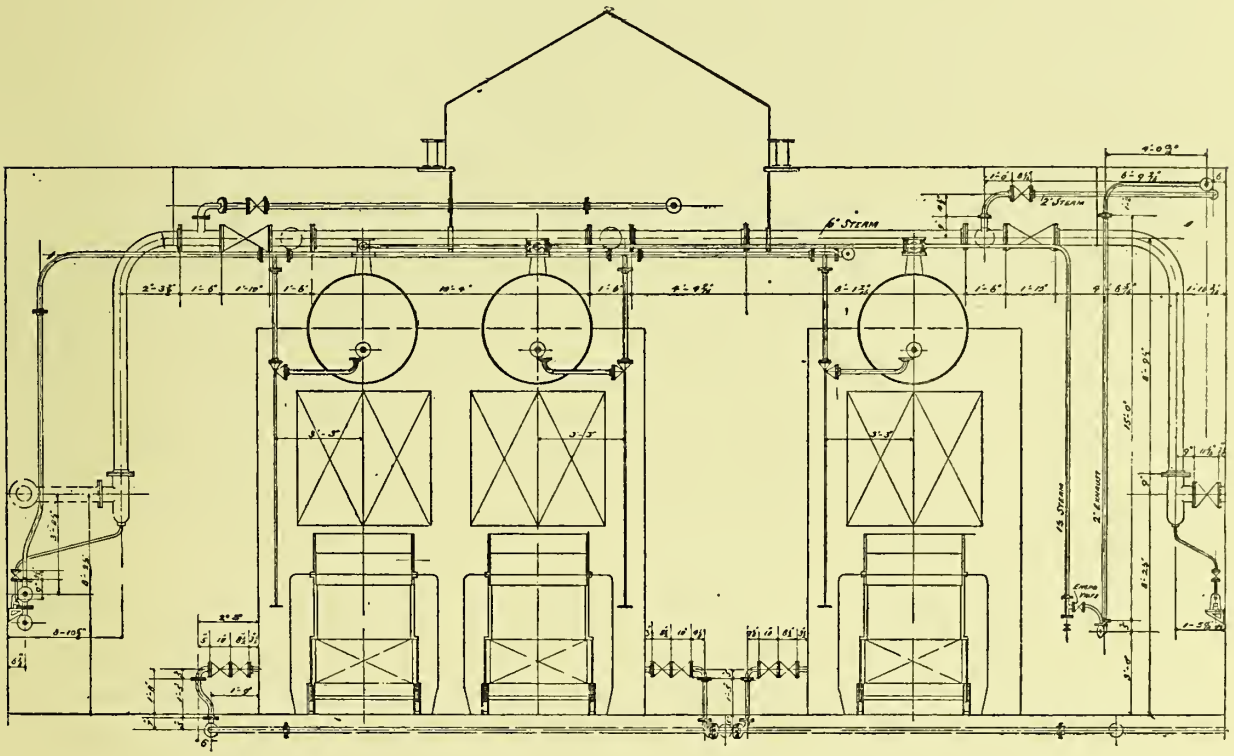


FIG. 27.—STEAM-PIPES, FEED AND BLOW-OFF FOR THREE WATER-TUBE BOILERS: ELEVATION.

ideal manner; that is to say, vertical and horizontal sections of a plain drum with dished ends exhibit symmetry in design with symmetrical lines of stress, or nearly so.

A large shell boiler is not easy to get in or get out of many boiler-houses in an awkward, restricted site. It is a common arrangement to in part set a battery of Lancashire boilers before completing the boiler-house—that is to say, such method of procedure is often convenient and sometimes quite necessary; whereas in the installation of water-tube boilers, the drum and various component

parts may be—are, in fact—ordinarily delivered to the site in separate packages. The several parts are erected *in situ*, including tube-expanding, in the boiler-house. This may be an enormous advantage, quite sufficient at times to turn the scale in favour of the water-tube, when there is any debate as to the type to be adopted. Again, where vertical space is more easily gained than superficial area, the water-tube is a far more suitable apparatus than the large shell boiler ; for, as we have already seen, 30-ft. boilers require a considerable width for their proper housing.

The proper sphere for the water-tube boiler in building-engineering—meaning engineers' work outside the commercial and industrial world—seems to be institutions having a heavy lighting-load and large hotels.

The accompanying drawings, Figs. 26 and 27, illustrate a battery of three of the famous Babcock and Wilcox water-tube boilers. The boilers represented are those supplied to the Metropolitan Asylums Board for the Darenth Asylum. Each boiler evaporates 5200 lb. steam per hour, and has 1462 square feet of heating surface. The drawings give all the pipe lay-out details—steam headers, stop-valves and connections, and arrangements for feed and blow-off. The design of the steam piping ensures elasticity, and the combined forces of gravity and momentum are employed for steam-drying ; the drainage is by steam-traps as indicated. Messrs. Babcock and Wilcox's patent continuous-drive chain-grate stokers are fitted, the steam and exhaust-pipes to stoker-engine appearing on the drawings. The grouping of two and the isolation of one of the units of the battery well suits institutional work, where the summer load is generally one-half of the winter.

As respects feed water it seems as unjust to entertain prejudice against the water-tube boiler as to condemn a chronometer because its action would be upset by using axle-grease as lubricant. It would seem but fair to judge the merits of different types of boiler from a datum of pure soft feed. Moreover, the high-pressures ruling in modern engineering practice demand more careful attention to water, whatever the type of boiler. As bearing on this point, the following, from the 1906 report of Mr. Michael Longridge, seems pertinent:—"The number of furnaces damaged by overheating during the year was unusually large, the cause of the overheating in most cases being accumulation of deposit. This generally happens in a dry year, when the supply of surface water is diminished and the springs are low, but more especially since the recent rise in steam pressures, for there is not the slightest doubt that, with thick plates, large diameters and high pressures, Lancashire and Cornish boilers fail to carry safely the quantities of deposit they did when pressures were lower and furnaces less diameter."

CHAPTER VIII.

STEAM HEATING.

To take up in detail the question of building-heating, the institutional engineer must rely on either steam or hot water as a heat-conveying medium. Direct heating by coal or coke furnaces is of little service excepting in laundry drying-stoves or in hot-air baths; and, although something might well be attempted with electric radiators as supplementary to a general steam or hot-water system, and as supplanting stoves in hospital wards, the cost of complete electrical heating is outside that which is practical.

There are a number of systems open to the heating engineer. He may have either simply hot water from a hot-water boiler or hot water from a steam calorifier, either live or exhaust, and the circulation can be either natural thermo-syphonage or forced by means of pumps. In these cases water is the medium of transference from coal combustion and the actual radiation from iron surfaces. Where steam is the medium this may be live or exhaust, either above, below, or at about atmospheric pressure. These methods understand the separation of the water and steam, i.e. heat is conveyed through metal; but there is a system worked out in some variety of detail whereby live or exhaust steam is discharged into the water-pipes by a kind of injector, approximately following the method adopted in the heating of swimming-baths. It depends chiefly on the nature of the institution as to exactly which system best suits. Herein is somewhat markedly put forward the forced hot-water system; but it does not necessarily follow that the centralised calorifier is the best. The indications are strongly in favour of the arrangement in straggling country institutions; even for compact town buildings, with an engineer's department well placed with respect to the centre of gravity of the load—as we may reasonably put it—there is much to say at times for centralised calorifiers. The present tendency is undoubtedly towards an extension of the forced hot-water system for new institutions, and to remodelling and centralising engineering plant in old buildings, both as to heating and domestic supply. It should be noted that error may occur in forced water systems, it requiring considerable care in design to ensure satisfactory heating at all points. On the other hand, there are many ordinary thermo-

syphonage systems that suffer from a sluggish circulation, especially on starting from all cold. This, in such buildings as theatres, may lead to inconvenience. To cut the pipes at a suitable point and insert a small motor-driven centrifugal pump is a useful recourse, and quite feasible in many installations.

The main question of steam *v.* hot water generally presents itself when a new heating system is contemplated. Ignoring the details of systems, and the fact that the type and purpose of a building may determine the question after a review of the conditions, it is useful to make a comparative study of steam as such and of hot water with respect to their suitability for conveying heat from point to point. Where the phenomena of condensation so largely enter into practical questions, a sound and reliable "steam theory" would seem highly desirable. We may look upon steam as highly energised and individualised independently-acting H_2O molecules. Yet, inasmuch as steam may be wet or dry with a varying degree of dryness, and may be also superheated, this, if admitted as a main theory, requires refining, being, in the stated terms, too crude to assist detailed consideration of conditions and effects.

If saturated steam were represented by the completely freed water molecule, moving in straight lines (the kinetic hypothesis), the question arises: What is superheated steam? It is this latter condition that suggests the absolutely individualised water molecule, and if this be admitted the condition known as saturation becomes the problem. If superheated steam is temporarily gasified water, and the isolation of each molecule is complete, mystery still exists; for the uncertainty among chemists as to the exact nature of vapours generally makes it impossible to more than hazard that saturated steam is characterised by some molecule aggregation, more or less, in proportion as the dryness fraction is greater or less. It might also be reasonably considered that perfectly dry saturated steam is true water-gas, and that the act of superheating merely quickens the motion of translation of the already isolated ultimate particles of water.

In questions of scientific steam-heating these minute considerations of steam nature and steam phenomena are not without their uses. They concentrate attention on the conditions likely to conduce to a satisfactory and economical use of the heating medium. We all see the locomotive exhausting to atmosphere, great quantities of steam heat. The heating engineer reflects that beyond a distance of a few inches from the rim of the smoke-stack all, or practically all, heating power has vanished. The surprising rapidity of steam condensation seems the chief point to hold in mind when considering practical matters, and is evidently a paramount point in the question of steam *v.* hot water.

If we imagine a ball so perfectly elastic that it will continue to rebound from a perfectly elastic floor and ceiling for an indefinite period, such a state of

things may be taken perhaps as a crude illustration of the kinetic theory respecting true gases. The difference with steam might be that at floor and ceiling the ball must continually receive a pat to keep it on the move. It is possibly to be demonstrated that the ultimate particle of dry steam must be—or in all probability is—*imperfectly elastic*. This is theory; if the theory be sound then there is a practical deduction; that no amount of protection or lagging will ever *prevent* condensation. It may be ameliorated, but not obliterated; and where proposals are made to carry steam for miles in pipes for heating, we cannot but think that the designer must hold the idea that the steam may, by suitable coating and protecting devices, be preserved from all, or practically all, condensation, and this in the face of the refined experiments and research of specialist natural philosophers.

It is not denied that great care and thoroughness vastly reduce condensation; and that wonderful results in the preservation of heat (and of cold) have been shown in recently invented flasks. The point is that the steam particle must be non-elastic, that in practice heat from somewhere is taken to maintain an artificial elasticity (or its equivalent and resultant effects), and that this heat is taken from one possible source only—other steam particles.

In questions of economical power production the point is met by superheating as a compromise; and it is a question for heating engineers whether exactly the same conditions, effects and recourses are not at times equally justified in their work. The necessary apparatus is a simple addition to the steam plant. Fig. 30 shows Messrs. Tinkers' Ltd. superheater for a Lancashire boiler. The condensation of saturated, and especially of hypersaturated, steam (as from engine exhausts) is plainly a matter of a few instants, and the relative losses are found less in the superheating system. In any case, dry steam is as important to the heating as to the power engineer. The point is generally overlooked. In both cases water in the steam is not only loss, but injury, if of a different kind. We see calculations that so much heat resides in exhaust steam; but the more practical point of preserving this by suitable connections between engine and heater is neglected, beside the fact that steam may be issuing from the engine in one of an infinitely varying degree of wetness. It is impossible effectively to plan any steam installation for power or for heating, unless the steam is considered also, and at the same time, as water.

One ton of steam passes down a steam main and heating branches and condenses in radiators. How much water results from condensation? The answer, neglecting actual loss by leakage, and any possible curious chemical theories, is 2240 lb. Presenting the position in this manner may give emphasis to the important practical point that condensation mains and drainage systems

are every bit as important as live steam mains and connections. It is not generally observed. A wealth of labour may be put into the correct arrangement of the more visible steam-pipe system, while the condensation details receive scant consideration—steam-traps thrown in here and there, and condensation mains run like the traditionary dog's hind-leg, it being argued that the steam will force the water along ugly bends and up-grades, which may be correct enough, but is not the method of a true workman.

All thoughts respecting steam-pipe should, therefore, in heating business be accompanied by equal consideration for the water of condensation. It is impossible to avoid an idea that the impression generally exists that steam pipes, if protected, will carry steam any distance. No one doubts this. In existing heating instal-

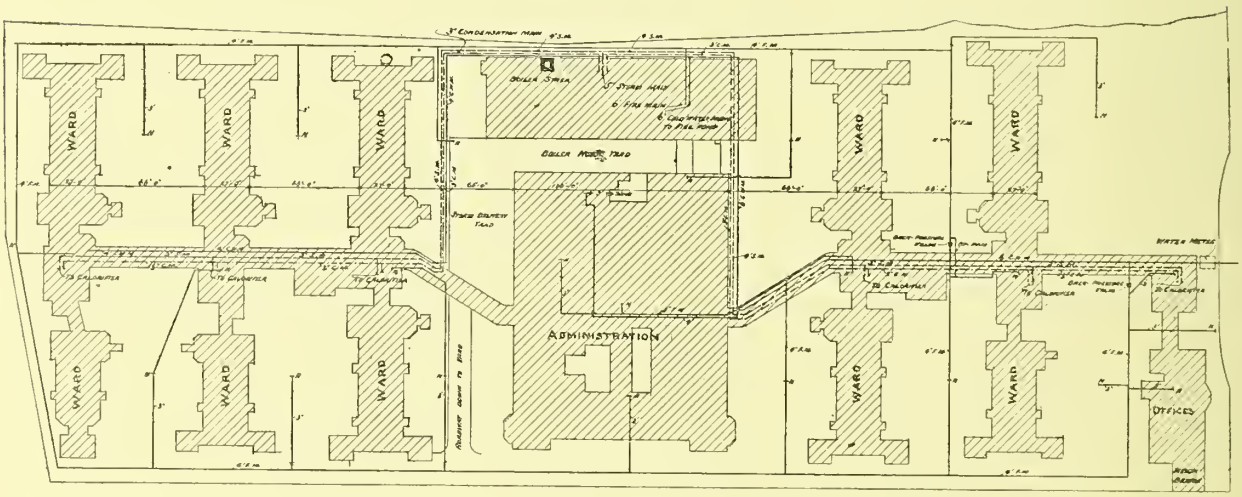


FIG. 28.—THE INFIRMARY, BETHNAL GREEN, N.E.:
BLOCK PLAN, SHOWING STEAM, CONDENSATION, WATER, AND FIRE MAINS.

lations miles of steam-pipes may be found; while in America a steam supply company carried steam for long distances below public thoroughfares. The question is not so much as to whether steam can be so conveyed as rather to what proportion of steam passed down the mains emerges as steam into the several radiators, etc. On this point not much actual light has been thrown, beyond the existing data of experimenters as to the amount of steam condensed under known conditions per foot run of certain diameter of pipe. Yet the question is vital to the heating engineer, and not a very difficult subject for scientific experiment.

We may bring up in sharp contrast to the sudden disappearance of steam heat, as shown at the locomotive funnel and to the mental eye in the condenser, the observed fact that a tub of hot water left overnight may in the morning appear

surprisingly warm, and that there is no kind of comparison between the loss of heat in steam in seconds and hot water in minutes—one might fairly say in hours even. Steam turned into the atmosphere becomes vapour instantaneously, or practically so. Water may be turned into a tank at 212°, and we have to wait a long time before venturing to put a hand therein.

These are facts of everyday observation, but might be more often remembered when commencing to make plans and decisions in heating, and when faced with the various aspects of steam *v.* hot water. Everyone knows that steam-pipes require protection, but it seems generally ignored that the recourse is palliative merely.

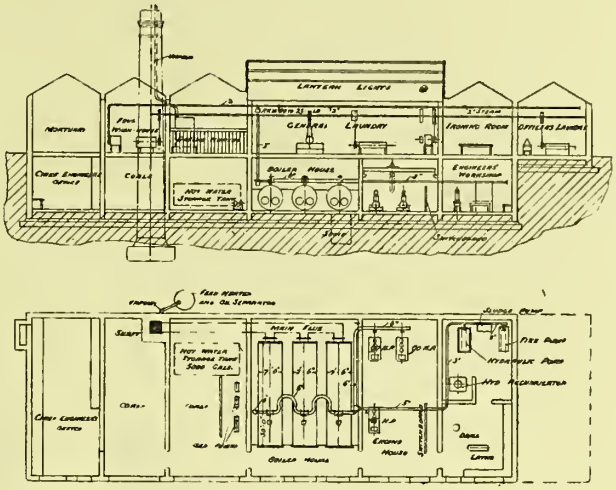


FIG. 29.—THE INFIRMARY, BETHNAL GREEN, N.E.: DIAGRAM OF ENGINEERS' BLOCK.

In discussions respecting the relative merits of steam and hot water we may frequently hear it advanced that the heat loss is relatively equal in steam and in hot water. In a sense this is plainly correct—so much chilling influence is present and so much heat is radiated, whether water or steam ; or, as more correctly put, to warm a given volume of air takes so many units, whether from steam or hot water. The direct inference too often drawn from this consideration seems to be that the question of steam *v.* hot water in heating buildings can need no discussion, excepting as to special systems and their merits and detail.

The present considerations refer chiefly to the conveyance of heat long distances. The only practical alternatives are steam or hot water. The point is, in which system is the least loss of heat—questions of the suitability of steam or water in radiators, etc., not now concerning us.

We produce one ton of steam, and desire to send the heat 1000 yards ; shall we lead the steam along the mains or convey the heat to water and send this along ?

In handling steam we deal with a sensitive substance. It contains more than seven times the heat of hot water raised from a normal 60° of temperature. Its potential rapidity of condensation suggests that the safest course is to immediately condense to water, just as if we have a sovereign of vital importance not to lose it is a safe procedure to convert it into pence. This is the essential point, and is

theory; but, judging by the immense saving in coal bills that is reported from large institutions where, in place of long steam mains, instant condensation in water and water-pipes have been substituted, the theory is sound. The moral seems to be--avoid long steam mains. The scientific reason is unquestionably the fact that steam is only maintained as such by taking heat from other steam. Compressed air remains compressed air, its energy is inherent and perpetual; while the steam particle is virtually a shot projected from a gun, destined to lose its energy and come to a

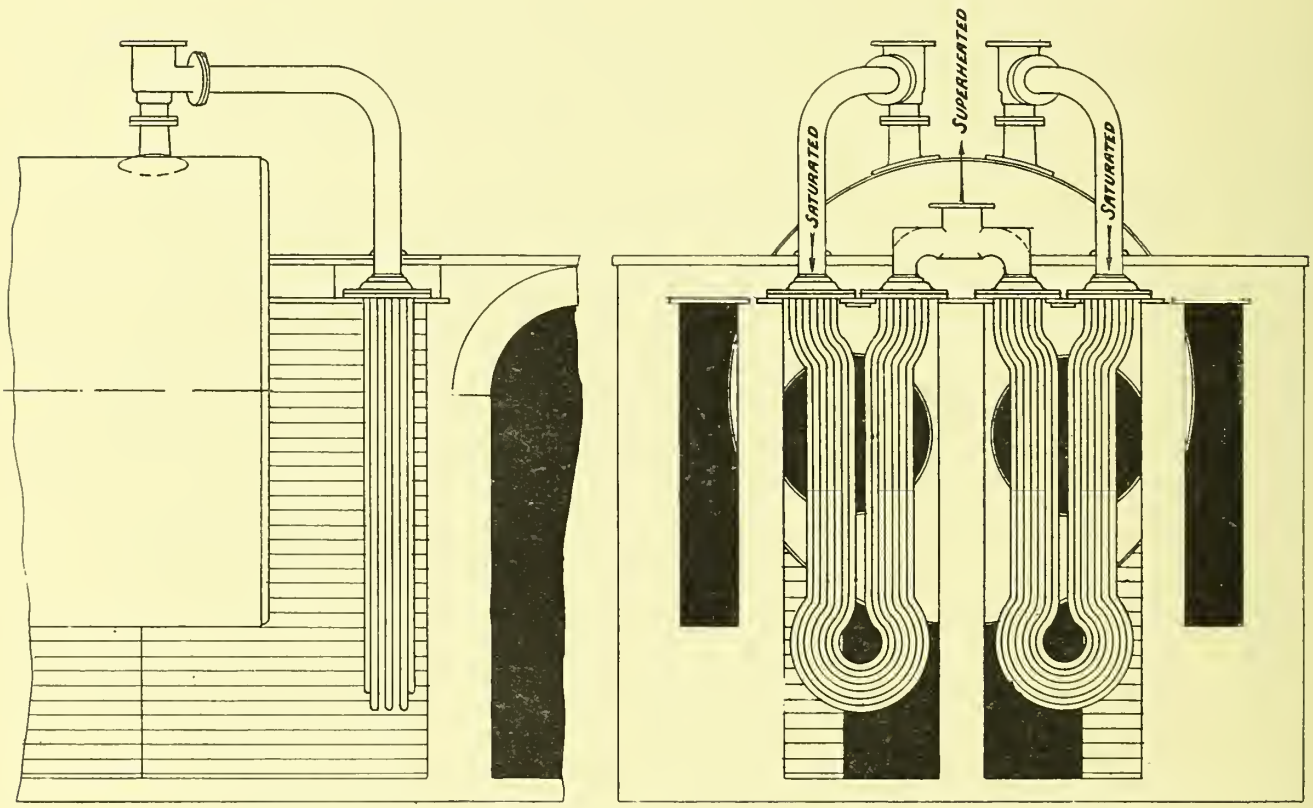


FIG. 30.—SECTIONS OF SUPERHEATER.

standstill—condense, whatever covering may be placed over pipes. As a fundamental plan, and quite irrespective of modifying conditions and considerations, it seems as reasonable to immediately convey steam heat to water as to bring up an object close to a gun if we desire to take advantage of initial muzzle velocity. As a practical outcome a calorifier is best placed close to the exhaust port of an engine; and it may be also noted how the considerations would lend weight to the advice of those heating engineers who say--Do not raise steam at all unless you require power.

It is further suggested that steam-pipe coatings should be complete. We see many steam mains with coats most neatly bevelled off at the flanges, the exposed flanges forming most excellent radiators—if loss by condensation were the objective. And it is only a grade less important that even hot-water mains, where of large diameter and great length—as between the isolated blocks of country institutions—should be protected. The annual saving in coal amply justifies the initial outlay on an inexpensive form of non-conducting composition.

In some forms of town institution the compact grouping and special feature of ground plan may well justify manifold calorifiers and short steam mains to these, and in such cases the smaller steam mains may be considered as a saving (in first cost) as against the more expensive large diameter hot-water mains with a central heater. Some forced water systems have given trouble from inequality and variation of the temperature at various points. It is a good point of steam that, quite irrespective of losses by condensation, the heat (temperature) is always available at distant points even if it really means extra coal; for steam has its temperature constant—such as arrives at the distantly placed calorifiers—quite independently of the fact that some of the steam may disappear—lose its heating power—in the mains.

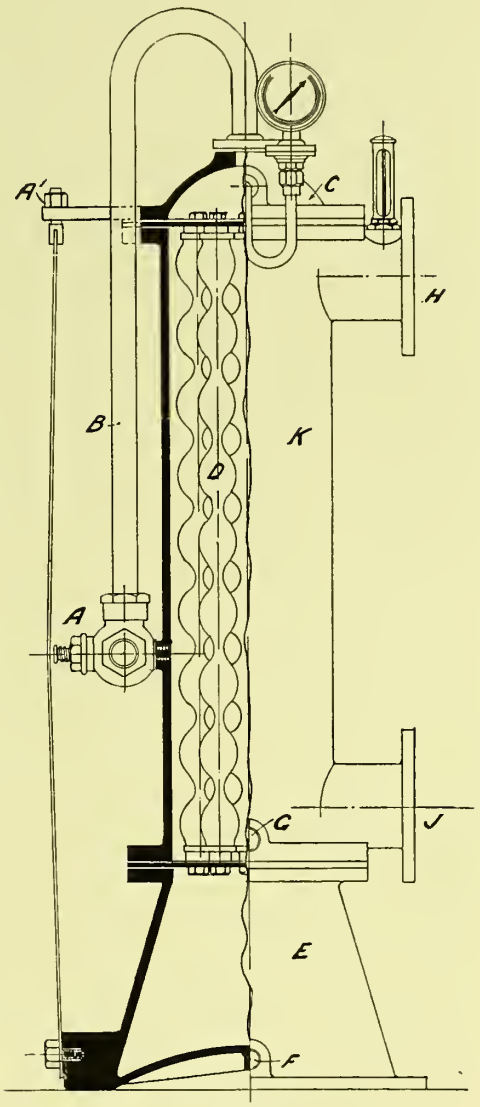


FIG. 31.—LIVE STEAM CALORIFIER: HALF SECTION.

A, automatic steam-valve; A^1, regulator; B, steam-pipe; C, cover; D, solid-drawn copper tubes, indented; E, base; F, condensation drain; G, connection for cold water from cistern or main; H, hot water flow; J, circulation return; K, body.

The author is indebted to Mr. David Thomas, the clerk to the Bethnal Green Board of Guardians, for the accompanying plan—Fig. 28—of the board's infirmary at Cambridge-road, Victoria Park, N.E. The plan shows all the steam, water, condensation and fire mains about the infirmary. The system is one comprising live steam supply to calorifiers. Each ward block

has a heating and water supply calorifier. The plan shows the sizes of the main pipes. The fire-main service is direct from the water-supply company, and the pressure can be increased by a special fire pump, as indicated on the drawing, back-pressure valves being arranged to this end.

The engineering arrangements at the infirmary are shown in the diagram, Fig. 29, and comprise three Galloway boilers 30 ft. long by 7 ft. 6 in. diameter, three electric generating sets, two of 90 and one of 45 h.p. The boilers have an efficient type of induced draught furnace with special fire-bars, whereby the fuel used may be of the cheapest mixture of slack and coke-breeze. In this way Mr. G. F. Broadley, the chief engineer to the board of guardians, has been able to reduce the coal bill by several hundred pounds per annum.

Reference to the block plan and diagrams shows that from the boilers 5 in. steam mains lead in as direct a manner as possible, under the exigencies of the plan, to the calorifier chambers in the basement of the infirmary blocks, the main pipes being suitably reduced in diameter as they proceed farther from the boiler-house. Condensation returns by condensation mains of from 1½ in. to 3 in. diameter. The boiler pressure is 80 lb. per square inch, reduced to 25 lb. at the calorifiers. The returning condensation water enters a large (5000 gallons) hot well or storage tank, from whence it is pumped into the boilers. Additional feed is heated by the engine exhaust in a special economizer, which is substantially a combined heater and oil separator.

The economies that can be effected in poor law institutions, where the guardians are fortunate in the possession of an expert chief engineer and of a clerk who is an enthusiast in engineering questions, is well demonstrated by the results at Bethnal Green. Reference has before been made to the recent Local Government inquiry and report on institutional engineering questions. In that report occurs the following:—

"In this connection the committee would call attention to the following extract from the triennial report of the Bethnal Green Board of Guardians:—

"The cost of coals for 1901 (before the introduction of cheaper coal) was—

Infirmary	£4840 3 6	
Workhouse . . .	2793 5 3	
Schools	731 16 6	
		£8365 5 3

"The cost for the year 1906 was—

Infirmary	£2969 16 8	
Workhouse . . .	1608 5 8	
Schools	515 7 4	
		£5093 9 8

a saving of £3271 15*s.* 7*d.* in 1906, as compared with the year 1901. This is more than equal to a rate of 1½*d.* in the £ on the present rateable value of Bethnal Green."

It is to be observed that the actual heating at the Bethnal Green Infirmary is by hot water; but extensive steam mains are in use, and for this reason the example is included in this chapter. Very little direct steam heating is now employed in large institutions. An example of direct steam heating—actual steam in radiators—is given in Chapter IV., Fig. 17, the schools at Leytonstone, London, E. The diagrams, Figs. 4 and 5, refer to direct steam-heat radiation, with an exhausting pump to maintain a certain degree of vacuum, an excellent plan where actual steam-heated radiators are contemplated. Indirect steam heating may be a suitable term for the arrangements included in the Bethnal Green Infirmary. The medium transferring the actual steam heat is the calorifier. Fig. 31 is a high-pressure, live-steam calorifier or water-heater by the firm of Royles, Ltd., who have long specialised in this form of appliance. The ideas of the present-day institutional engineer tend greatly in the direction of centralised calorifier batteries, heated by live or exhaust steam, and with forced water circulation through the actual heat radiators or heating pipes or coils. The example of institutional engineering given in the succeeding chapter shows steam-heat immediately conveyed to water. Colloquially, both Fig. 28 and the arrangements at Camberwell Infirmary, and also Homerton Infirmary, are examples of "hot-water heating." The systems are here differentiated, because at Bethnal Green steam is conveyed in long mains, and questions concerning steam and its phenomena must largely enter into any lay-out on this system. The term "hot-water" heating originally intended a water-heating boiler, pipes or radiators. The use of the calorifier as a medium and of either centralised or distant and manifold calorifiers has somewhat involved the significance of the terms.

At Camberwell Infirmary, discussed in the succeeding chapter, not only is there hot-water heating, but actual steam-heating in some wards, etc. In many institutions this use of different systems is adopted. Thus it may be convenient to carry a short steam-main to a special building and condense the steam direct in radiators, or the same may be done in coils as for heating laundry drying chambers. All such direct-steam heating needs, more or less, steam-traps discharging into condensation mains leading to hot wells Considering how many are the ways of using the steam for heating a large and heterogenous collection of institutional buildings, it is not easy to keep solely to hot-water heating and solely to steam heating. Both systems are well understood at this day. The attention of the reader is therefore in preference directed to that compound steam-and-water heating method just now in vogue in institutional work, and constituting a practice likely to be extended on similar general principles.

CHAPTER IX.

HOT-WATER HEATING.

In the preceding chapter certain considerations were made leading to the conclusion that institutional engineers should seriously inquire into the claims of superheating for steam supply. We held principally in view the system where a central boiler-house supplies steam to manifold calorifiers. The chief defect in this system is condensation in the mains. It has, however, the advantage of assuring at least 212° of temperature at the calorifier in each block of the institution. Regarding the collection of buildings as one body corporate, all parts are equally warmed. The drawback generally is the extra coal burned in evaporating steam that never reaches the calorifier tubes. Superheating, by maintaining the temperature of steam above condensation point, enables one to conserve the latent heat, the loss of which is far more serious than the expenditure of a relatively few heat units in superheating. Superheating, careful insulation (pipe covering), and high pressure up to and as far only as reducing valves, are the indications for heating engineers concerned with the manifold calorifier system in large institutions; and for compactly-arranged blocks, with a well-placed boiler-house, the general system may often have special advantage. High-pressure steam in mains, if free from condensation loss, brings about an economy corresponding to the saving of "copper" by high tension in electrical installations. The cost of great lengths of large diameter hot-water mains must be taken into consideration.

The alternative system of heating extensive institutional buildings has hot water in the mains, although not necessarily hot-water boilers. Where, however, steam is concerned, whether live or exhaust, the desiderata are rapid and efficient conveyance of steam heat to water and a vigorous and real circulation. These aims are effected by bringing the calorifiers close to the boilers or engines, and the avoidance of long connecting mains. For institutions covering many acres of ground no arrangement of natural gravity flow and return pipes can bring about the desired vigour of circulation. Even in small buildings it is frequently a defect that the hot-water system heats up slowly from all cold, and the evil is especially inconvenient in such places as theatres. The advocates of steam-heating have one very potent argument—its power of rapidly heating up from all cold.

The deficiency—sluggish circulation—of hot water is well overcome by the system of forcing the water by pumps through the mains that pass along to the several blocks of institution buildings. The general idea is not to force water through the branches and radiators, but so to arrange matters that a supply of water at a high temperature is available at a position that may be said to stand for and represent the calorifier chamber of the manifold calorifier system with steam connections to a central boiler-house. A complete arterial and venous circulating system in mains and branches is an extension of the fundamental idea, and has a practical gain over the simple one of forced main circulation and thermo-syphonage in branches. Such a system represents a complete exposition of "two-pipe" hot water fitting. Its advantages are positive flow through all radiators. The heating engineer can generally arrange for final satisfactory results in the fitting-up of details in an ordinary gravity hot-water installation, by adopting two- and one-pipe and overhead principles according to the exigencies of each special portion of the system. Although the "one-pipe" system looks unscientific and crude, it is yet based on sound fundamentals, the most prominent of which is the fact that a section of a quasi-horizontal pipe conveying hot water in a steady-flowing stream exhibits the phenomenon, and quite naturally, of hot water at the upper part and cooler water at the lower.

The object of the simplest forced hot-water system is to provide flow and return mains, with such effective movement in the pipes that a high temperature may be present at considerable distances from the calorifiers. It should, however, be noticed that this *high tension* system of hot-water mains again brings about an equivalent to saving in "copper," for to attempt anything on the same scale with thermo-syphonage would need great diameter of mains and a great body of water in the main system. A vigorous flow will need a less diameter of pipe, much as the high voltage reduces necessity for cross-section of cable; and it seems indicated practically that a relatively small main—not sufficiently cut down to set up great frictional resistance—might connect with take-off pipes for branches of increased area of cross-section, giving high rate of flow in main and more body in the take-off pipes—practically, large T-pieces.

There are two ways in which temperatures might be controlled in the forced water system—(1) by amount of steam supply solely, maintaining constant rate of pumping, and (2) by varying both steam condensed and number of pump strokes per minute. Those who have had practical experience of the working of the system advocate the former method with unvarying pump speed, ascertaining by trial the rate of flow best suited to the particular building or group of buildings.

In a lay-out of the forced mains system of heating, it is well to preserve the

old graded arrangement whereby one pipe becomes virtually an ascending flow, and also a descending return. But this is by no means a necessary proviso; one of the great advantages of the system being that, due precaution being taken against trouble from air, the mains can indifferently be laid up and down or level, as may be convenient, and obviously such convenience may very frequently be present in country buildings much spread about and covering acres of undulating ground.

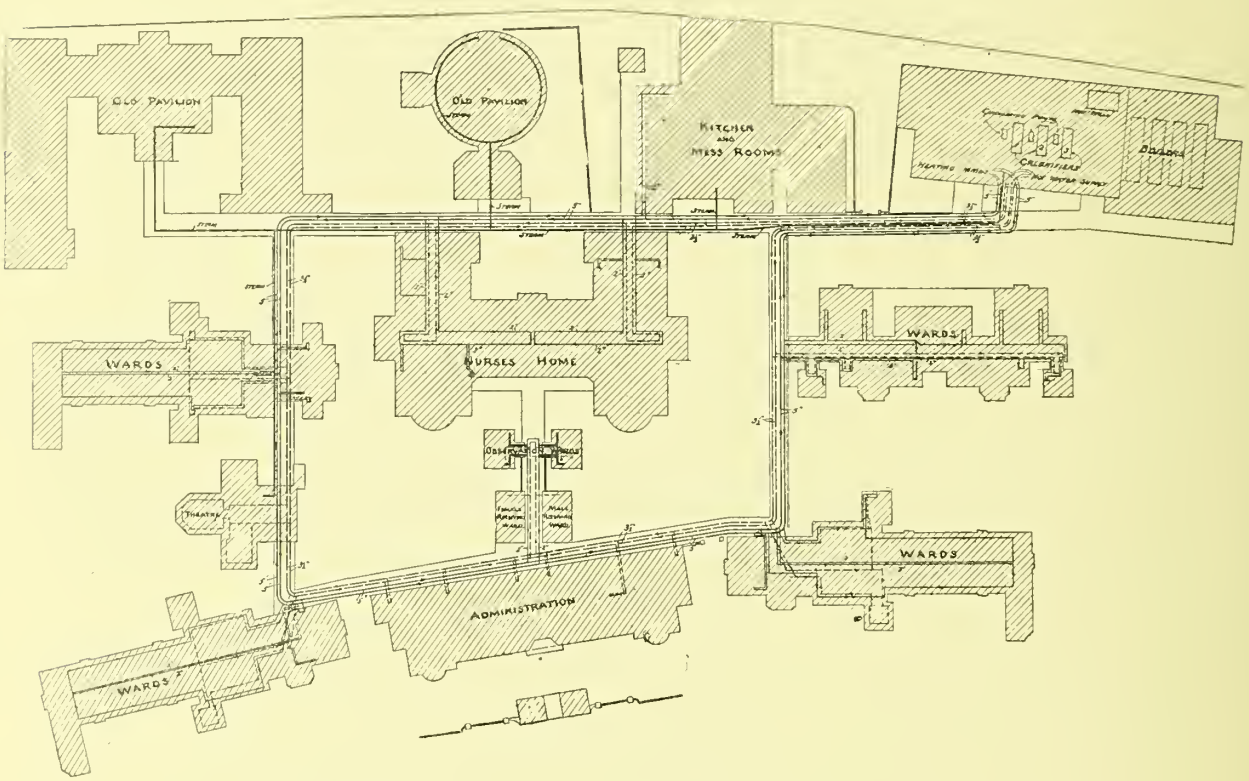


FIG. 32.—CAMBERWELL INFIRMARY: HEATING AND HOT WATER SUPPLY MAINS.

The pipe mains are best laid on a ring system, as under this system pipes that start out as flows may be used as returns, and vice versâ, while, by placing suitable stop-valves and three-way valves at branches, or principal junctions (as to each block), the whole block may be isolated, and yet the remainder of the buildings duly served by the thus amended system of flow and return.

In laying out the lines of the principal mains, it should be seen if possible that the position corresponding to the highest point of gravity flow-return mains have no duty, because here naturally the ring system has its lowest temperature,

and temperatures that most nearly coincide; that is to say, one should see that at this particular point the duty is unimportant.

An interesting example, and one that has been much studied by those contemplating a similar system, is the heating of the Camberwell Infirmary. The author has to thank Dr. Keats, the medical superintendent, for the accompanying instructive plan of the mains and branches at the infirmary.

It will be seen that eight main pipes cross from the engineers' block to the subways connecting the several buildings. Four of these pipes carry the hot water supply, and are $3\frac{1}{2}$ in. bore; the other four are heating mains, and are 5 in. bore; the 5 in. flange-coupled and protected from cooling. Two of each set of pipes are flows and two returns. The pipes are graded in the subways, so that their highest point is about at the theatre block. The system is, therefore, that two heating pipes start away as flows, and come back, virtually, as returns into the calorifier chamber. In this way a ring system is formed both for heating and hot water supply, and stop-valves and three-way valves at the connections to each block enable short circuits to be formed in the main systems, and any necessary repairs carried out in any block without interfering with the other block services. Under the buildings are subsidiary (branch) horizontal, graded flow-return pipes with vertical risers to the radiators on the several floors. The water supply is throughout arranged with flow and return branches—to lavatories, baths, etc.

Four large Lancashire boilers are provided, with special induced draught furnaces which enable a low grade of coal to be burned, whereby great economies have been effected in the annual fuel bill. There are three calorifiers, one for heating, one for hot water, and one as a stand-by, each having its corresponding circulating pump. Exhaust steam, supplemented when necessary by live steam, is used in the calorifiers, which have copper tubes, and are provided with safety valves. Either the heating or water-supply heater can be connected to the stand-by plant by operating a simple arrangement of stop-valves. A 7-in. diameter flow pipe connects the calorifier, and a similar size collector is provided for the returns. A certain amount of supplementary live steam heating to kitchens, old pavilions, etc., is provided as indicated on the plan.

Camberwell Infirmary is one of the largest in London. It was designed by Mr. Edwin T. Hall, V.P.R.I.B.A., who instituted the forced water plan. The work was carried out by Messrs. Dargue, Griffiths and Co., the engineers for the infirmary heating system. The system of forced water circulation has been largely adopted in many recent institutions, and was employed at the South Kensington Museum, from plans by Mr. E. G. Rivers, M.Inst.C.E. Mr. W. T. Hatch, the engineer-in-chief to the Metropolitan Asylums Board, has also adopted

the system in several of his designs. It has been used at the Shenfield Pauper Schools, Hutton, Essex, a rambling institution affording a most suitable scope for the general principle.

It may have occurred to the reader that possibly in some way, in place of the ordinary duplicate (heating and supply) mains, as at Camberwell, one set of pipes might be made to fulfil both duties. The objection to such an idea is sufficiently obvious—water employed for heating cannot, under the conditions ruling, be made fit for supply purposes. Did not this obstacle exist, the supply of water could be taken out of the heating pipes, greatly simplifying the whole plant. Such an arrangement would save a pair of mains.

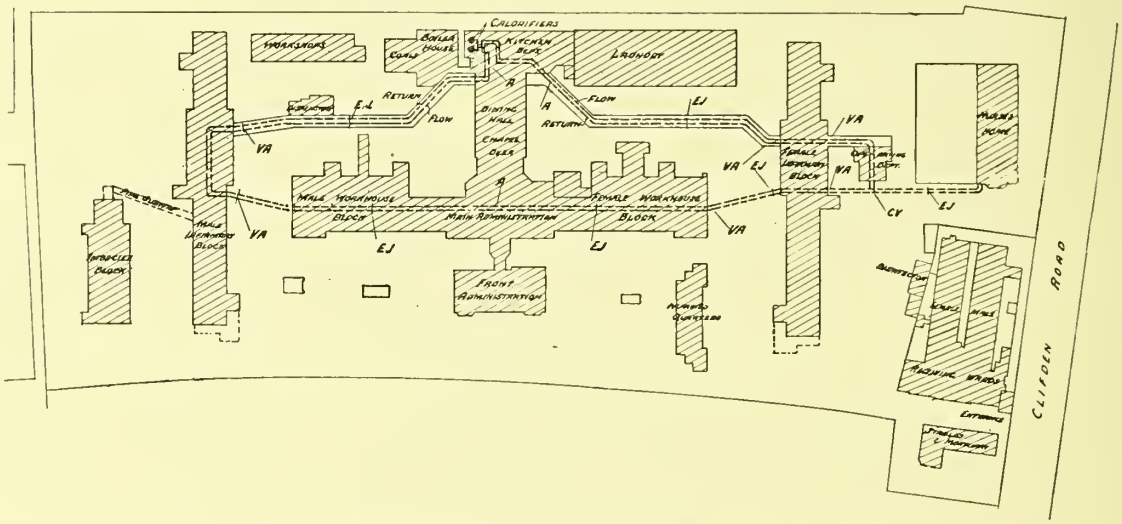


FIG. 33.—CITY OF LONDON UNION, NEW INFIRMARY, HOMERTON, N.E.: BLOCK PLAN, SHOWING HEATING MAINS.

A, anchor; E J, expansion joints; C V, control valve; V A, No. 2, 3-way stop-valves and anchor.

An ingenious system has, however, been installed at the new infirmary of the City of London Union at Homerton, N.E., whereby some approach is made towards the general idea. Only one set of mains is employed—for building-heating. The water is circulated by centrifugal pumps on a ring main system generally resembling that at the Camberwell Infirmary. At certain points in the institution are placed supply calorifiers. These are heated by the building heating mains, a kind of "water-heated calorifier" being provided, hot water circulating through the tubes where in the ordinary way steam passes. The main building-heating calorifiers are heated by live steam. Fig. 33 gives a block plan of the institution, and generally shows the lay out, and the mains and the steam calorifiers, but does not show the water-heated calorifiers, which are suitably

distributed in the several building blocks. Figs. 34 and 35 give details of the arrangement of the steam calorifiers in the calorifier chamber, with their electrically driven circulating pumps, stop-valves and connections. The system of heat-transference may be compared to that in the heating of feed-water by placing coils in the tank, through which passes condensation water, a recourse not infrequently adopted where such water is greasy and no oil-separator is installed—as in odd pumps in power stations—or on such occasions as where it is estimated to be practically more economical to run a little condensation water to waste rather than incur the expense of connection to a distant condensation main.

The author has to thank Mr. Edward R. Woodward, the Clerk to the Guardians, for obtaining the permission of the Management Committee of the City of London Union to publish the accompanying drawings and details of the novel and interesting system of heating supply water. The infirmary was designed by Mr. A. E. Pridmore, F.R.I.B.A. The buildings are partly old and partly new. The central block is an old building, which is at present used solely as a workhouse. The block near the entrance is also old, and consists of receiving rooms, casual wards, maternity wards, etc. The new buildings comprise the large

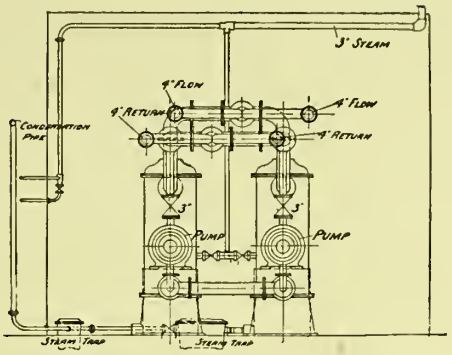


FIG. 34.—CITY OF LONDON UNION, NEW INFIRMARY, HOMERTON, N.E., LIVE-STEAM CALORIFIER AND SPARE: ELEVATION.

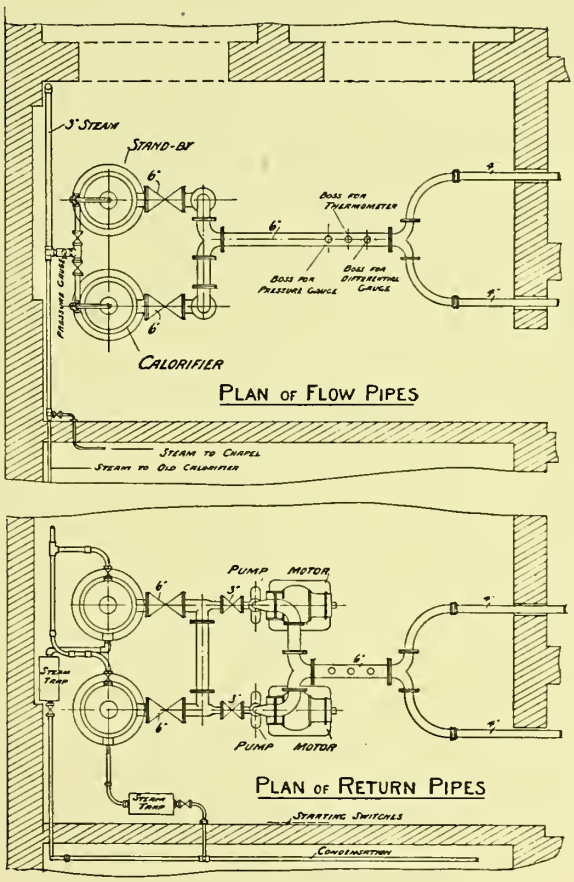


FIG. 35.—CITY OF LONDON UNION, NEW INFIRMARY, HOMERTON, N.E., LIVE-STEAM CALORIFIER AND SPARE: PLANS.

infirmary blocks, each consisting of three stories, a nurses' home and imbecile block, laundry, kitchen, and an extension of the old workhouse, including a new administration block. The buildings have been designed for the accommodation of 681 inmates and 63 officers, at a total cost of about £55,000.

It was originally proposed to provide each block with its own heating boiler and hot-water service boiler, and to generate steam for the laundry, kitchen, etc., in an existing boiler-house, but subsequently the guardians appointed Mr. E. R. Dolby, M.Inst.C.E. (of the firm of Dolby and Williamson, of Westminster), as consulting engineer, who prepared a report advising that fuel combustion should be centralised; and that, instead of detached boilers at different points, two large

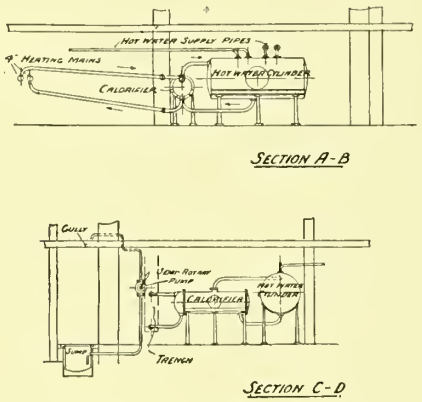


FIG. 36.—CITY OF LONDON UNION, NEW INFIRMARY, HOMERTON, N.E., WATER-HEATED CALORIFIER: SECTIONS.

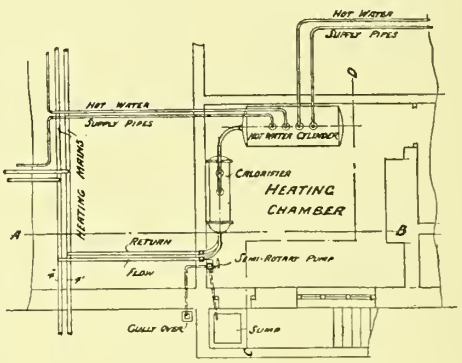


FIG. 37.—CITY OF LONDON UNION, NEW INFIRMARY, HOMERTON, N.E., WATER-HEATED CALORIFIER: PLAN.

steam boilers should be installed in the central boiler-house, each boiler to be large enough to do the entire work required; and, further, that from this central point the heating should be carried out by hot water on a system of reinforced circulation, the hot-water service to be supplied in a similar manner.

The entire heating is carried out from the main calorifier chamber as a central point. In this chamber are installed two of Royle's calorifiers, each large enough to effect the heating, not only of the water for building heating, but also for hot water service.

In the same chamber also are installed two centrifugal pumps coupled direct to two electric motors, each sufficient to carry out the whole work. The water heated in the main calorifier flows round the ring main in the pipe subways, as

indicated in Fig. 33, the circulation being reinforced by means of the centrifugal pump which draws from the return and delivers the cool return water into the calorifier, in passing through which it becomes reheated. The water in the ring main and the calorifier is never changed, and thereby acts as the heat-conveying medium. In each of the blocks branches are taken off the ring main to supply the subsidiary mains which feed the radiators on the several floors. In each block a branch loop is also taken to a hot-water calorifier, which produces the whole of the hot-water service required in that block. Each such calorifier is coupled with a storage tank, as shown in Figs. 36 and 37.

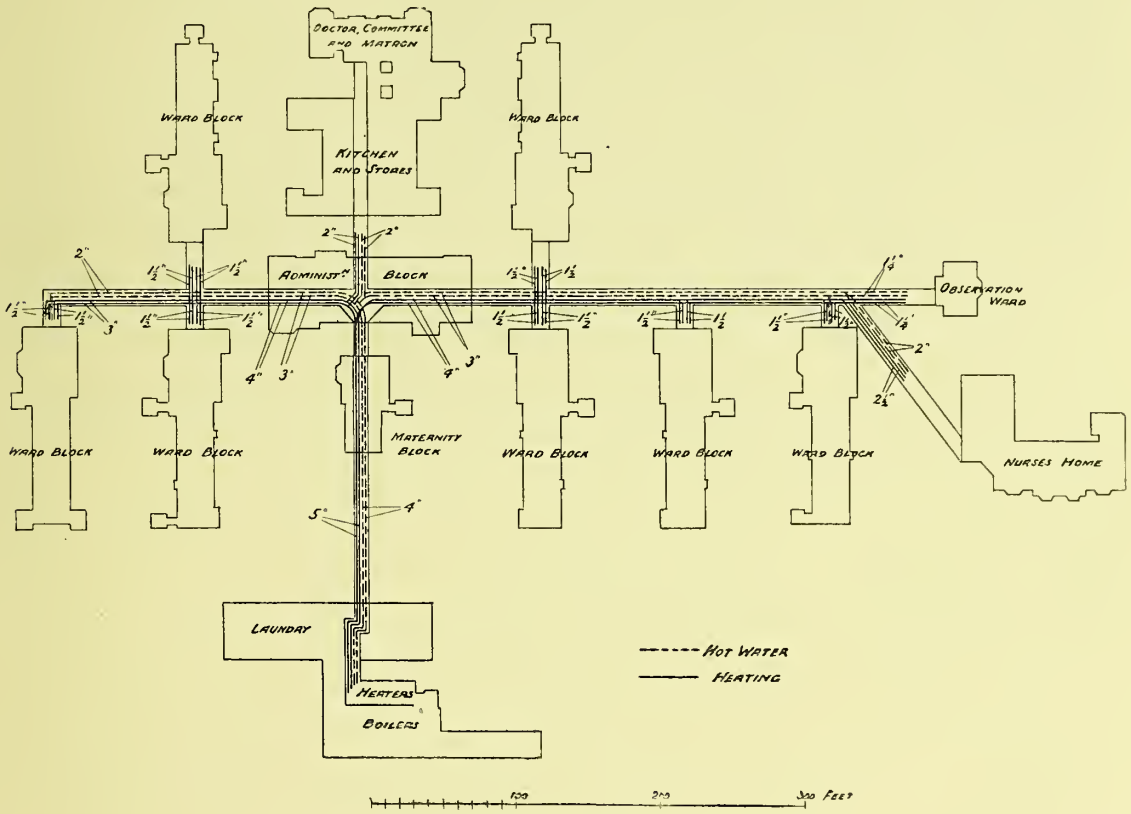


FIG. 38.—SOUTHAMPTON INFIRMARY: BLOCK PLAN.

The most scientific system of centralised heating must be considered to be that having actual forcing through mains *and all branches*, radiators, etc. This is sometimes termed the "positive flow" method, and also the "tree" system. This principle has been adopted, with ingenious improvements in detail, by Mr. C. Eddington Merrall, the consulting engineer for the pending alterations to the heating and hot-water supply at Southampton Infirmary. Fig. 38 is a block plan

of this institution, showing the proposed arrangement of main and branch pipes. The numerous calorifiers dispersed about the various building blocks are to be taken out, and two large central heaters are to be installed in the engineer's block. From these new calorifiers, heating and hot-water supply mains are to be laid in the pipe subways, of sizes as figured on the plan. The whole is an exposition of a complete "two-pipe" system with pumping through all parts. The advantages are many. Radiator and supply temperatures are reliable, constant and equable at all points, perfect control being given by suitably-placed throttle-valves. Great economy in first cost of mains and branches is gained, the expense of long, large diameter ring-mains is avoided, and generally the branch pipes are about one-half the size required in less scientific systems. Radiator connections are reduced to $\frac{1}{2}$ in. Mr. Merrall's proposals for heating and water-supply at Southampton Infirmary must be considered to represent the most advanced practice in centralised heating for large public institutions.

A large amount of institutional building-heating is accomplished with the plain hot-water "boiler," and the construction of such is, at the present day, an extensive business. A favourite design is the "sectional" boiler. Numerous public buildings, schools, small infirmaries, town halls, libraries, hotels and theatres are well served on a system practically that of the old-time greenhouse heating. Into the details of this system it is unnecessary to enter. Numerous text-books and formulæ make the requirements common knowledge, and most village plumbers have theories on the subject.

CHAPTER X.

EXHAUST STEAM HEATING.

An ordinary rate of condensation in radiators is from $\frac{1}{4}$ to $\frac{3}{10}$ lb. steam per square foot of radiating surface per hour; hence the practical rule that allows $\frac{1}{3}$ lb. steam per square foot per hour in steam heating. A first-class institutional electric-lighting engine should require about 25 lb. steam per horse-power hour. As nearly as can be, exhaust steam contains 75 per cent. of the practical thermal value of the coal. Of a total of 12,000 B.T.U. in the fuel, after utilising dynamic energy and after heating feed water, 9000 units are approximately available for building-heating. The consideration indicates the waste occurring where exhaust is to atmosphere, and points to the desirability of at once conveying the heat to water, one cubic foot of which, losing one degree, is approximately capable of warming 3000 cubic feet of air one degree of temperature.

The average institution requires more coal-burning for building-heating than for electrical energy generation, so that in most cases we find that a supply direct from boilers supplements the exhaust to calorifier, and this is the more necessary because, while the heating load is approximately constant, the lighting and motor load widely varies. In some cases a pressure-reducing valve controls steam to the exhaust calorifier, bringing the two pressures equal; in others the engineers depend on regulation by simply throttling, while some again instal a back-pressure valve in addition. Back pressure is not so great an evil as it would appear, since the loss to the engine is approximately as the difference between back pressure and mean pressure, or, say, 50 lb. mean pressure and 2 lb. back pressure above atmosphere is only 4 per cent. loss to the engine, and only about, and not more than, 1 per cent. of coal.

Fine calculations as to the amount of available and workable steam-heat in exhaust would be misleading, so far as forming a practical basis is concerned, a general consideration that 75 per cent. is available being sufficient, and even this requires to be considered with caution, for the reason that the condition and quality of steam must greatly vary. We find gratifying results set out as to the evaporative power per unit weight of fuel, at and from 212 degrees; but it has been demonstrated that boilers may be passing over as much as 25 per cent. of water

with the steam, which, deducted from stated results, takes the gilt off the apparently phenomenal results. If conditions rule that between the engine exhaust outlet and a calorifier, great condensation results—or, in other words, if either through the main or subsequently passing through the cylinder water is present in large quantities—by so much is the supposed available steam-heat impoverished. Hence, as a practical deduction, as much care should be taken to protect exhaust pipes between engine and calorifier as with actual live-steam mains. The natural tendency on exhausting is to dry the steam—by reason of the fall in pressure—so that if ordinary precaution is taken against unprotected pipe evils, and it is seen that the length of pipe is short and direct, the conditions about exhaust-heating are in favour of the engineer; while with every pound reduction in pressure the relative amount of latent to total heat increases, leading to a suitable hot-well temperature, or conversion of state (steam to water) at steam-traps under conditions favourable to general economy. High-pressure calorifiers, powerful—space for space—and requiring only small dimensions, are at a disadvantage in one respect: that the condensation occurs at a temperature so high that somewhere between the steam-trap and the hot-well considerable loss of heat-units must occur, and in this fact is to be sought, perhaps, some explanation of a remarkable statement made that where steam is supplied direct to calorifiers, the boilers require more forcing than where the steam first passes through, and does work by engines.

Where heating or hot-water-supply calorifiers are designed for exhaust steam, appliances and details suited to exhaust conditions must rule; the live-steam auxiliary must work down to suit. Either a large or two or more small ones in series may be arranged according to convenience, and where any mistake has been unfortunately made and much steam blows away up the atmospheric or vapour pipe, the considerations above made show that the recourse to a back-pressure valve may be a compromise ensuring higher efficiency, or, in other words, less loss to atmosphere. Many positions will no doubt come to mind where steam is puffing away up a vapour-pipe, generally alongside a boiler stack, where it is supposed, in the engineers' department below, that they are well utilising the engine exhaust. Such conditions rule about sundown, in large hotels, and the position corresponds to, and synchronises with, the uprising of dense clouds of vapour from cooling towers, what time the peak load commences to appear in the power station engine-room.

To have the potential 75 per cent. steam-heat from exhaust and to utilise this seems two different affairs. To connect a long imperfectly-protected exhaust pipe to a small calorifier with a few tubes and blow steam to atmosphere—or the residue of the exhaust steam—may be so inefficient that the prime cost of the appliances might as well have been saved and the whole exhaust conveyed up a vapour-

pipe. The tube surface must be designed to condense at or about atmospheric pressure the amount of steam required to fulfil duty under maximum demand. Hence it is well to err on the side of generous tube area and ample size of calorifier.

In grouping three interchangeable heating and supply calorifiers, a compromise requires to be effected in design, because the conditions affecting the heating and the supply apparatus are not alike. In the former case the use over and over again of practically the same water causes clean surfaces even at high temperatures; in the case of the supply heater the constant change of water leads to scale formation, and eventually to pitting, very similar to that in steam boilers. Any kind of tube suits in the heating calorifier; for the other, straight tubes, easily cleaned, are desirable, in fact necessary; and when the design of such is reliable, the system of automatic valve control—as by expansion and contraction of bars, etc.—should be installed. It not only prevents scale, but actually economises steam, by preventing useless increment of temperature. Again, where oil remains in exhaust steam, this will deposit in tubes and lower the efficiency of the apparatus by checking heat transference, slowing the action. Hence, steam turbo-generators have special and valuable points for institutional work, being practically free from oil in the exhaust. Small turbines are now being put on the market.

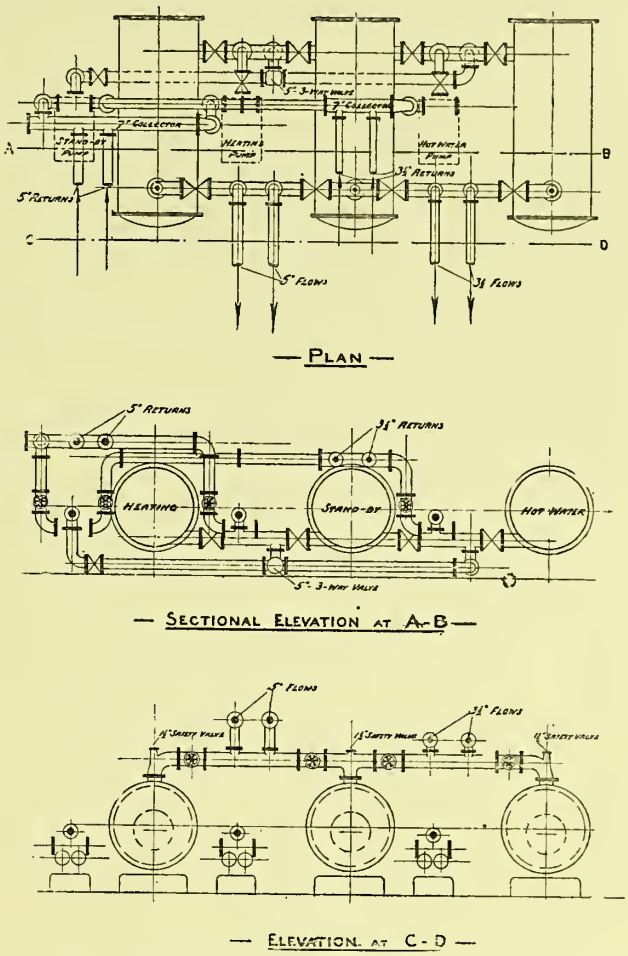


FIG. 39.—HEATING AND HOT-WATER CALORIFIERS, WITH SPARE.

One of the largest type of water-heaters was installed in the Shoreditch Baths. The exhaust passes through the three heaters, which are arranged in series, the engines working ordinarily with a back pressure of 5 lb. The three calorifiers shown in the accompanying Fig. 39 are those installed at Camberwell Infirmary

for heating and domestic hot-water supply. The exterior heaters are for heating and for hot-water supply, the central one being a spare, and thus either of the two may be for heating or for supply, and any one of the three may at any time be under repair.

The Camberwell Infirmary system is described in the preceding chapter. The heating mains are 5 inches, and the hot water $3\frac{1}{2}$ inches. It will be seen that these are collected and distributed by short lengths of 7-inch pipe. Stop-valves and three-way valves permit interchanging. The bodies of the calorifiers are of $\frac{1}{4}$-inch steel plate, riveted, and the plain tubes are of copper, the steam passing therethrough.

Ordinarily, the engineer specifies stock-heaters, many varieties being made by specialist firms, such as Messrs. Royle and Co. The firm have an indented "Row" tube, giving undoubtedly increased heating efficiency, this type of heater having been supplied for water-heating at the Dowlais Baths. Two or more heaters in series may save, and be as well as, special design for large examples. The principles of design include ready access to tubes—easy cleaning of the tubes of the water supply calorifier, and an efficient auto-control valve, safety valves to both steam and water spaces and suitable thermometers for the charge engineer's guidiance, and safety air-valves. Vertical design is considered superior, and in horizontal types it is well to set the apparatus with a slight fall, it having been shown in surface condensers that efficiency is largely influenced by the readiness with which condensation water is freed from tube surfaces, a desideratum that led to the invention of the "Contraflo" condenser.

Many makers of feed heaters have improvements and devices that would be useful in calorifiers proper—vertical types with vertical boilers, and vertical feed and circulating pump render it possible to pack up the plant for building-heating by steam into a very small space.

In arranging circulating pumps with calorifiers, the pump should force through the heater because, under these conditions, the temperature of the water can be raised higher, and it is, further, some advantage, possibly, that cooler water passes through the pump. Arrangements can be made for auto-control in combined live and exhaust calorifier plant. A regulating valve is required near the boiler, and the live steam passes a reducing-valve. Exhaust is made into this low-pressure system. On the pressure rising when the exhaust steam is in excess, the special valve closes. In the event of a yet further rise of pressure, a back-pressure valve opens, and excess of exhaust discharges to atmosphere.

Some time back the author suggested, and practically investigated in a series of articles, a proposal to build public baths adjoining municipal power-stations, surface condensers to be employed, and the bath water passed through the

condensers. The idea is worth consideration by municipal engineers. The waste of heat in cooling towers is necessarily enormous. At evening load, too, there is difficulty often in maintaining a good vacuum on account of the inefficiency of the over-heated mats, etc., in cooling towers, a common temperature of cooling water at discharge being 130 degrees. Under these conditions auto-relief valves approximate to equilibrium, and vapour appears intermittently at the atmospheric pipe.

It was proposed, too, that the filling, and the emptying also of swimming-baths, should pass through the condensers. A cooling tower, with specially designed by-passes and valves, was to be arranged, and a large, well-protected hot-water storage-tank seemed indicated by the investigations. If not altogether practical for institutions, an elegant problem would be presented by an investigation of the conditions, assuming a large lighting and motor load, condensing, and some means whereby live steam increased building-heating water-temperature, suitable enough for baths service, but not for the former duty.

In viewing such a site as that of and adjoining the East Ham power-station, one cannot but reflect that in similar positions, if the municipal power-house, baths, fire-station, library, etc., were grouped together, much heat from coal combustion could be saved, that now ultimately disappears as clouds of vapour.

CHAPTER XI.

VENTILATION.

The present position of the heating and ventilating science—the "state of the art"—leaves much to be desired. A fundamental error is the taking of air heating as a basis. Radiant heat, is what is required, and walls, floors, and ceilings actually warm; and radiating warmth seems a better foundational system. Although we cannot return to the old Roman hypocaust, yet much is to be done by efforts to obtain pure radiant heat as against mere heated air.

As something ideal we can conceive of electrical cables disposed in walls much on the principle of the bottoms provided to electrical kettles. Such a system is of course impossible under the present state of knowledge, and the cost of electric heating. Nevertheless we are convinced that having arranged a practical system of general heating by steam or hot water, the hospital designer would find that the place of coal fires and stoves could be well taken by electric radiators, the small amount of current required, as relative to that which would be necessary for general heating, making this proposal practicable. The glowing electric radiator is pleasant to the eye; it even has the advantage over coal fires that the intervals of blackness at renewing the fuel are absent. It is complained that the daily carrying of coal to wards constitutes a nuisance from dirt and dust, besides requiring much porterage in large buildings. Yet doctors generally advocate fires as supplementary, and as we think wisely, the factor of cheerfulness being of importance as curative; hence those who so advocate are not, as is supposed by some, sentimentalists, but "scientists."

The modern hospital ward is the nearest approach to an open-air camp that can be practically arranged. The old theory excluded draughts as pestilential, but the present-day physician throws open windows. We can therefore quite understand the objection of the medical profession generally to elaborate ventilating schemes, as against the free breath of heaven. To tell such that on a fine, genial day they must close all windows and draw air through small pipes and ducts is an insult to their intelligence and to common-sense; hence in hospitals, whatsoever may be the arrangements for cold and damp weather, the summer-

time provision must be for wide-open windows and a practically open-air life for patients. Under such conditions fans and ducts are anathema.

Left to himself, every medical superintendent would depend on fires for heat and open windows for ventilation. On fundamental principles he is correct, and no amount of argument would convince him otherwise. As a type, the English open fire and open window are unapproachable, despite the adverse criticism. There seems some unique, some life-giving, property in the main atmosphere that is lost in detail, that is to say, to put a fainting person directly in the open air has apparently a different effect from supplying air to him through a pipe.

Assuming that the attendants and staff in wards keep themselves warm by the exercise of their duties and by clothing, the problem of warming and ventilation for patients is simple, the one being sufficient blankets and the other the open window—free entry of large quantities of air undoctored and in its natural condition. The modern treatment of consumption shows that this system may defy all kinds of weather, the sole requirements being a roof and blankets.

The general argument here may be deemed Spartan. It, however, has the sanction of the medical profession. In spite of the fact that circumstances alter cases and diseases, and their treatment must needs vary, as a fundamental plan the (practically) open-air system is a type to keep in mind; so that where a doctor requires such, it should be seen that he gets what he wants, any more elaborate provision being in the nature of a stand-by.

The remarks made bear equally on all kinds of buildings and apartments. In place of air supplied through a pipe in detail, the wholesale supply of natural air is the most healthful. It would be interesting to have a sum total of fans and elaborate ventilating arrangements provided for hospital wards that have been promptly scrapped by doctors and medical superintendents, who have as a substitute thrown open windows and adjusted the position of such windows to suit varying wind direction. This is rational, too, because a change of wind direction will often completely upset artificial forced ventilation in spite of rotating fans, inlets then becoming outlets.

Most doctors are dead against plenum ventilation—the system whereby air is warmed and forced through ducts into wards; and, as respecting fan ventilation, curious results accrued from some experiments in America. A forcing fan having been started, there were found *n* microbes per cubic inch of air supply. The speed of the fans was increased by steps, with the main result that, the faster the fan, the more microbes present per unit of measurement. The explanation was that more dust was stirred up as the velocity of the air increased, and

although one would say that there should rightly have been no dust, this is theory only, and practical conditions exist. Again, as respects fans, experiences have been described in ward ventilation where, on closing windows and relying on fan ventilation, patients fainted, with the final result that the fan system was abandoned and windows opened for the future. In this way, physicians become prejudiced against artificial ventilation.

It is to be noted that in many systems, or want of systems, of ventilation, where a fan exhaust and fresh-air inlets are provided, it seems wholly ignored that, as a result, a kind of short-circuiting may take place directly between inlets and outlets, and that the main body of air in the apartment may remain unchanged; and as a practical point there can be no doubt that a complete fan system must comprise forced entry and forced exit of air, otherwise short-circuiting may take place.

It is admitted that the general problem of ventilating and heating is difficult and involved, and we may easily abuse existing systems without being able to suggest improvements.

We may, however, fall back on fundamentals, and one of these is that where simple and natural means can be effectively used let elaboration be tabooed. A writer on school-planning expresses an opinion that the ventilating engineer seems to think that there is something evil in natural air, and that it is only after he has warmed, filtered and moistened it that it is fit for breathing.

Absolute plenum, in wards, the doctors will not consider for a moment; and they are right. Such systems, however, have their uses, for however we may argue as to the benefits of open-air and natural supply, how are we to adapt such to theatres or to apartments and halls, as in cities, connecting to the atmosphere only at, say, the bottom of restricted areas? Hence, we may reason that the system of ventilation must be adapted to circumstances, any nostrum suited to all varieties of apartments and buildings being impossible. Fans are good in places; so-called natural ventilation is good in places, and the Englishman and his open fire and open windows is sensible all round. Who would adopt plenum ventilation in a house? It is well to admit that modern heating and ventilating is a most imperfect science. The consideration will give pause where hasty conclusions would be made. It suggests simplicity and naturalness as a root basis. Admitting so much, we may proceed to inquire into the general aspects of practical methods and appliances having the open window and pure radiant heat as a touchstone of excellence.

Coal combustion is the origin of the caloric; steam, or hot water, or both, the media for conveyance to apartments. The question of method must turn on efficiency on the one hand and economy on the other.

Hundreds of open fires are an impossible provision in establishments having a thousand or so inmates.

Practical convenience and economy have of late turned the scale much in favour of hot water in radiators. Although the evil of "burned air," with high-pressure steam, is purely imaginary, it is real in so far that heated organic impurities give off unpleasant odour, and it would seem that the point here rests on the fact that where the boiling-point of water is reached or exceeded the small particles of dirt or dust become disorganised, with attendant smell. Hot water in radiators at less than 212 degrees has not this splitting-up action on "matter in the wrong place." Moreover, to the argument that steam is much quicker in action (heating-up) it is replied that, on the other hand, the temperature may fall rapidly on careless work in the engineers' department, whereas the slower heat-loss in hot water institutes a kind of buffer—is not so sensitive. Water-fittings are simpler, the amount flowing through radiators may be controlled where the stop-valve in steam radiators must be either full on or full off; so that, apart from the question of centralised or manifold heaters, the modern preference in institutional engineering for hot water, as the direct medium for radiation, has a sound basis.

Assuming that as a general consideration we lay down that hot water has the balance of the arguments, as a radiator of caloric in apartments, we are then faced with certain rather involved questions concerning the arrangement and position of radiators. Thus, it seems quite reasonable and natural to place radiators as ordinarily—at floor level and preferably under windows—on the main idea that heated air rises, and that an up current below the windows will counteract the disagreeable cold down-draught that will be frequently noticed when sitting below a large area of glazed opening; but, on the other hand, it is admitted that excellent results have been obtained with overhead radiation. This seems strange, despite the fact that the sun is overhead and not at our feet. Again, supposing that we follow the usual practice of low-level radiation, there enters the question of the details concerning the radiators themselves. Presumably from America came the terms "direct," "indirect," and "indirect-direct," as applied to exposed, concealed, and partially-shielded radiators respectively. In the one case we have direct radiation—an isolated, heat-giving body; in the others enters the principle of air-heating more or less.

Of the several styles and systems here scheduled, the medical superintendent would no doubt choose, on principle, direct radiation for hospital wards. It stands for, and represents, the open fire, and disseminates pure heat—from iron, it is true, which does not for some reason appear an ideal heat-giving material. It permits in wards warmth to occupants with relatively cool air to breathe,

which should be the aim. Such radiators, however, may not assist air-change—ventilation; hence are so far inferior to the open fire, which is an effective exhausting engine. Therefore, however excellent the isolated radiators for steam or hot water, where such stand as the sole warming agents, additional means must be taken to insure a change of air. For this reason, one finds a large use of what is practically "indirect-direct" radiation—inlets from atmosphere so arranged that air may be drawn over radiators, and in so doing be warmed or tempered. The so-called "ventilating radiator" thus has had a wide field of practical usefulness in hospital work. What is termed the "boxed-in" radiator is not kindly received by doctors, because of the difficulty of cleaning, but types are manufactured that have this cleansing in view in the design, while in practice a plain, isolated radiator placed in front of an air opening below a window fulfils most of the conditions at the base of the "indirect-direct" theory, and as such have had wide adoption in public buildings. Plain radiators beneath windows represent standard practice, and must at present be accepted as satisfactory.

The general system pertains largely in institutional work, and is accepted by the physician who believes in fresh air and plenty of it. The architect or engineer working on this principle in wards and day-rooms and communal apartments generally is here on safe ground. He cannot go far wrong; and it is most necessary that all such should be shy of introducing novelties, except and only under direct and written sanction from responsible authorities. To this simple heating and ventilating system we would be glad to suggest cheerful electric radiators centrally in place of the open fire or stove, and even if at an increased cost in electrical units generated; for against this cost there is a great set-off in the saving in fuel and mess and nuisance generally of carrying coals to the wards.

The above outline of a simple, practical system of heating institutional buildings, dormitories, wards, and day-rooms, etc., is a compromise, as we have said and argued. It has its objections in small detail, but in the present state of heating and ventilating, as a practical science and business, it presents a straightforward solution of the problem. Some will add exhaust fans, and the works of such may get rusty, because doctors do not always concur, and because they wish their patients as nearly as possible to lead the semblance of an open-air life, which, as they cannot take off the roof, they bring about by widely opening windows.

It is impossible to give a direct answer to the question: "What is the best method of ventilation?" The reason is that everything depends upon local conditions. If figures would suffice, the matter is long beyond dispute; but unfortunately while formulæ and data are necessary for the designer at his

drawing-board, he has first to lay a foundation of pure reasoning, which has nothing to do with squares or their roots. An examination of the building or its plans, local surroundings, neighbouring structures, climate, prevalence of winds, and their characteristics, the duty of the buildings and nature of their inmates, relative heights (as of pavilions) and aspect, are to the point, and all is necessarily bound up with mode of heating and resultant conditions. The main system is the thing: a simple diagram its best initial materialisation. On these as data may be constructed a working hypothesis—that the air will, or may by good fortune be hopefully expected to, behave in such-and-such a manner. Upon these cautious assumptions a working machine (virtually) may be constructed, and the best made of a necessarily more or less defficient science, the uncertainties of which are a measure of the instability of winds; all of which facts are patent to eye and ear in the flapping of light non-return air valves and the eddying to and fro at points and positions where constancy of current was the anticipation and hope. Fans may mitigate this. They can rarely negative the inconsistency of action.

A common cause of failure in ventilating schemes must be admitted to be the want of bold, generous measures. Of course, this means expense; but for one thing where without shadow of second thought we provide a hundred feet or so of bulky brick stack, as part of the device for warming inmates, we do not find the same broad treatment for the sake of a pure interior atmosphere. Yet, whether such a recourse be or be not ever advisable, we can appreciate at once the fact that the cap of a tall chimney is elevated far above surrounding constructions, and is thus at any given moment crossed by more or less constant horizontal air currents, and is attended by a steady water-gauge indication; and that, even if the velocity of the air varies, conditions are at the chimney-head altogether different from those about the ordinary low-level ventilating shaft. In these latter, at one time conditions favour exhaustion, at another (change of wind direction) there is a blow-down, either direct or reflex, from adjoining objects, walls, etc. Yet in very many cases to attain a measure of constancy, or at least an absence of direct blow-back, it will not be necessary to construct such a lofty ventilating stack as above suggested. A clear outlet, having equal conditions round about to the four winds would put matters on a different footing from that where abutting against a wind reflector of some sort. Another ten feet of brickwork in many cases would have made the best of things, and possibly have accomplished the fundamental idea in natural ventilation—automatic air exhaustion.

In thus, by hazard, drawing attention to a particular detail in ventilation—the finish of an automatic exhausting shaft—we have unconsciously shown, perhaps, wherein lies the need, not so much for mathematical calculations as to air

velocity, volumes and the like, as for general reasoning as to conditions, and this not only on basic matters but in smallest details.

It is reported that in the pre-sanitation era—of not many years ago, after all—a certain builder, in laying drains, came across a buried hollow tree-trunk; connected up, without paying any fee whatever, filled in and rammed, and perhaps reflected that what the eye does not see the heart does not grieve over. Much the same easy state of conscience seems to possess the designer of automatic ventilating shafts. A ventilating flue or flues are constructed and cropped off at the earliest opportunity for brickwork saving. Where such are at a low level, respecting roof ridges, and on the sides, say, of a pavilion, a cross wind establishes different conditions and results under reverse directions. Dr. Keats has described conditions under such circumstances: "I think that a good many of the theories as regards ventilating, and particularly those of consulting engineers for heating and ventilating pavilions, that is with heating and ventilating combined, fall to the ground for the reason that when you get more than one pavilion arranged side by side on a small site, the ventilation depends on the strength of the wind and the direction of the wind, and you get some extraordinary results. Suppose this is a long ward on the ground floor of a tall pavilion, and you have a ventilating apparatus in the building. The wind strikes the block and curves over the block and descends into the interval between this block and the next, then it edges right round and creates a current right round on the opposite side of the wind. You get currents flying backwards and forwards." This graphic description of an ordinary condition of things about a class of institutional building emphasizes the necessity for studying local currents and their effects before deciding upon systems and details.

If ventilating stacks of the type considered are to have a maximum of practical efficiency they must run clear of structures into free air, the cost faced and architectural effect ignored, failing that prime essential of the truly architectural—ability to render beautiful the necessary feature. Precisely similar conditions affect fans. We may talk learnedly of peripheral velocity and the like, but it is all vanity if the final position of exit is such that the fan must at times operate in the teeth of an opposing gale. The accompanying illustration, Fig. 40, comes in opportunely on this point. The drawing shows the basement at the Merchant Venturers' Technical College, Bristol, designed by Mr. Alfred W. S. Cross, M.A., Vice-President of the Royal Institute of British Architects, and with heating, ventilating, and water supply by Messrs. James Keith, Blackman and Co., Limited.

Attention is drawn to the fan, illustrated in Fig. 40, which exhausts air from the basement by suitable ducts, etc. The fan under the condi-

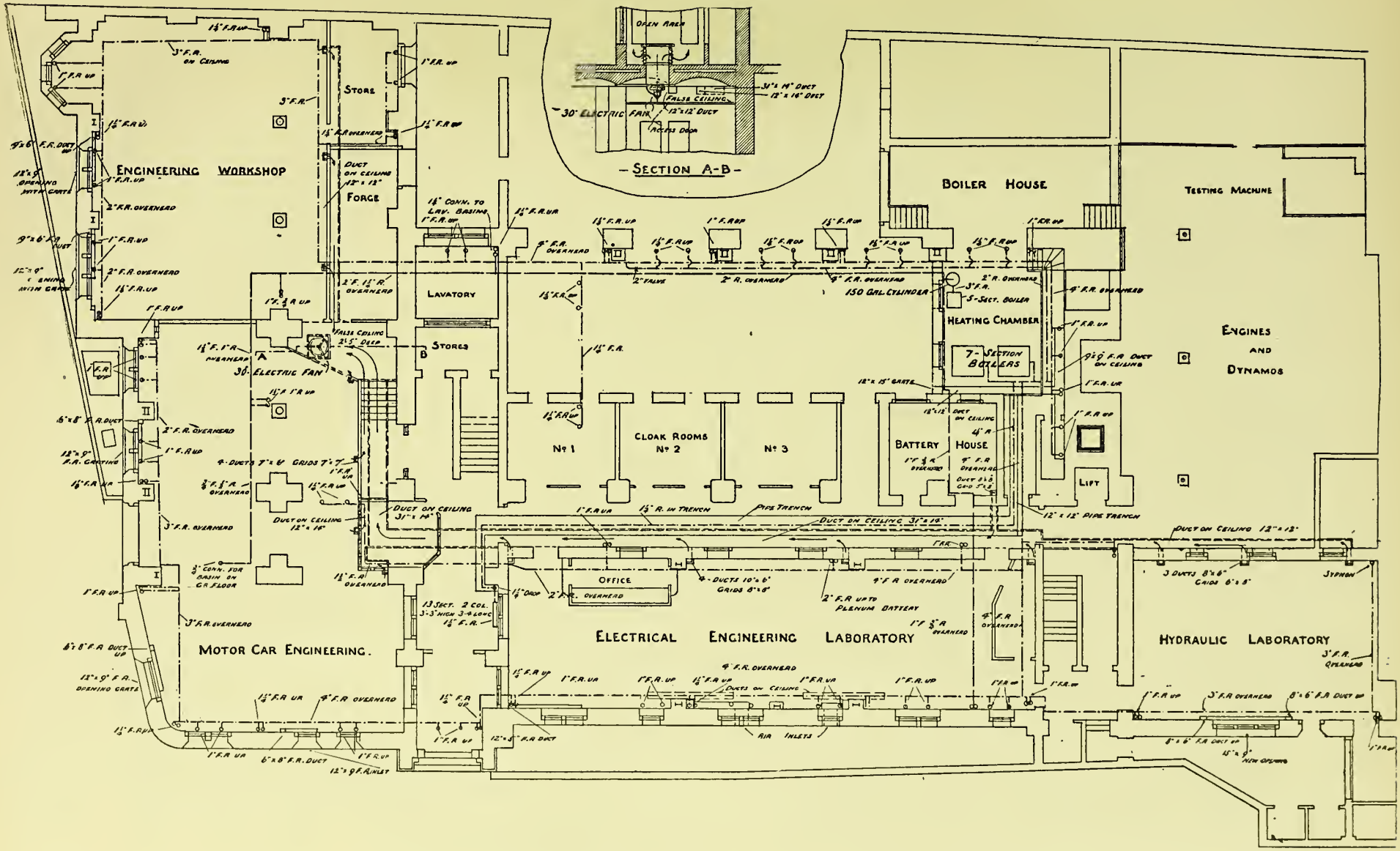


FIG. 40.—THE MERCHANT VENTURERS' TECHNICAL COLLEGE, BRISTOL: BASEMENT PLAN, SHOWING HEATING, VENTILATING AND HOT-WATER SUPPLY.

tions, and for the special duty, is well placed at the bottom of the area as shown.

If, on the idea of improving effects, a vertical shaft had been run up the area, and the fan fixed at the top, varying currents and chance down draughts would have been against its action, whereas in its position there can be little chance of any such influences. As it is, protected by an elastic buffer—the area contents—it can do its duty undisturbed. If we had laid down that all outlets of vertical ventilating shafts must be carried up to the highest point, this attempt to generalise laws for ventilation might have misled an unwary designer.

Figs. 41 and 42 show the third-floor plan and details of the plenum ventilation for the chemical laboratories, a most fit subject for forced ventilation. Fig. 40 shows that in a suitable chamber are arranged sectional boilers both for heating and for water supply. The heating system is two-pipe, the large mains 4 in. diameter, reducing as necessary to 3 in. and 2 in.; while $1\frac{1}{4}$ in. flow and returns serve the radiators. In most cases there are fresh-air inlets in the external wall, so that the entering air is tempered, and in the electrical engineering laboratory will be noticed two special ducts enclosing the overhead 4-in. flow and return pipes, and connected to air-inlets in the wall. Thus, the general system comprises heating by direct radiation, through the medium of hot water, and air-tempering by entry near to the radiators. This general system prevails throughout the ground, first, and second floors. The extraction of vitiated air is by means of electric fans in suitable chambers and connected by false ceilings over passages and ducts and openings into the several class-rooms. The basement is arranged as shown, having a separate, independent system of extraction by means of a 30-inch fan, with vertical spindle, discharging into an area at the side of the main stairs. It is to be noted that only one radiator appears on the basement plan, and it must be understood that the warming of the basement apartments is by the large flow and returns overhead; and inasmuch as there is some debate as to, and many have approved of, overhead radiation as a root principle, the arrangement may here be considered justifiable and satisfactory.

Up the area indicated in the section in Fig. 40 run vertical ducts that draw off by false ceilings, horizontal ducts, and openings to class-rooms the vitiated air from ground, first, and second floors. At the third-floor level are constructed two electric fan chambers, the fans having horizontal spindles, and being respectively 54 inches and 48 inches in diameter. These fans connect by suitable air passages or conduits to the vertical ducts in the area above-mentioned.

The arrangements for heating and ventilating the third floor are special and independent. On this floor are a chemical lecture theatre, chemical laboratories,

and a combustion room, needing serious measures for maintaining a comfortable state of things for the students and their instructors. The arrangement installed consists of forcing in warmed, and extracting vitiated, air by suitable fans—a variety of so-called plenum ventilation. On the flat roof of the third floor is constructed a concrete fan chamber, with also space enclosing a battery of hot-water radiators. The electric fan is 36 inches in diameter, and draws fresh air from two inlets over the radiators, and forces into a downcast, and so by a false

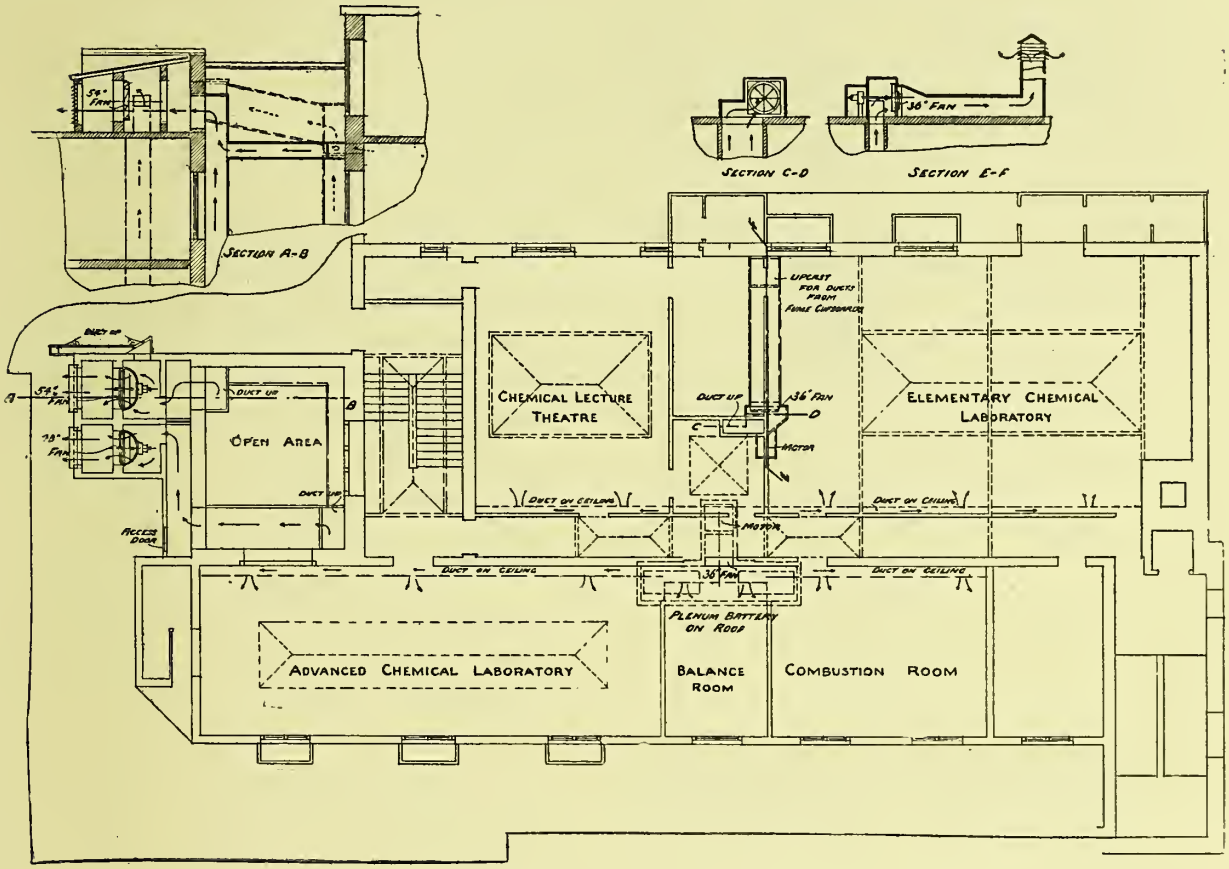


FIG. 41.—THE MERCHANT VENTURERS' TECHNICAL COLLEGE, BRISTOL: THIRD FLOOR PLAN.

ceiling and horizontal ducts with grid outlets into the several class-rooms. These outlets are at ceiling level. For exhaustion there is another 36-inch fan chamber on the roof connected to suitable ducts and outlets in rooms. Besides this arrangement of forced general ventilation the extracting fan also removes fumes from fume-cupboards by special ducts, presenting in all a very complete system of artificial ventilation for a difficult class of duty.

The original plenum idea seems to have been to force in fresh air leaving

the exhaust to take place in a natural manner, through either miscellaneous or designed openings. It is advanced for this system that it has the advantage that the air supply is pure, whereas by the system of mechanical exhaustion, air may be drawn in from undesirable sources. The main idea of actual plenum was that there would necessarily be a slight pressure above atmosphere in the apartment, a state of things brought about by the blowing fan, but the additional pressure is hardly worth serious consideration in any question of merits of the system. It follows that the use of both blowing and exhausting fans is not plenum, strictly speaking. It must, however, be considered a superior method for the reason that it tends to avoid the short-circuiting likely to arise, where a fan simply pulls air out of a room. The two fans should be equal in diameter, power, and revolutions per minute, for otherwise there is either a tendency to lower or raise the pressure relatively to atmosphere.

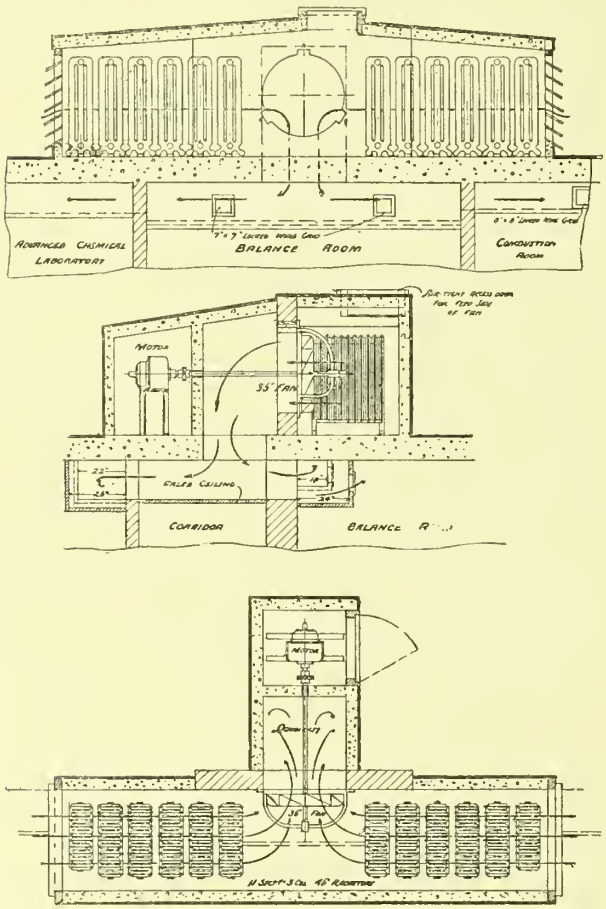


FIG. 42.—THE MERCHANT VENTURERS' TECHNICAL COLLEGE, BRISTOL: PLENUM BATTERY.

The most elaborate systems of ventilation include air filtration. The ordinary recourse are cloths stretched over frames, and, as in the case of some large city hospitals, revolving filtering screens may be provided, the lower part being passed through running water, whereby the screens are kept clean, and a certain amount of moisture may be thus added to the air. Generally, these elaborate arrangements do not appeal to doctors; but in works where the air is much liable to contamination, the forcing of fresh air through filters is a useful device.

An experiment recently performed at a London hospital is full of significance in questions of ventilation. Several students volunteered to be enclosed in an air-tight box. After a short time they naturally began to feel the effects of this

confinement. An electric fan was fixed in the box, but no fresh air could be admitted. On setting the fan in motion the occupants of the box at once became relieved and lively.

From this it is evident that fans may have a beneficial effect apart from their function as air displacers. The idea is that of the Indian punkah. Stagnation of air seems a great evil, and we may be led to think that frequently not so much a question of fresh air is at stake but that the air should have movement. The point has been much applied in practice, as evident by the great numbers of small electric fans in offices, etc., where the idea is not so much air supply as to create air currents, and for simple exhaustion an immense number of small fans have been fitted the last few years in apartments much cut off from direct access to the atmosphere. In such places as basements, etc., this kind of fan ventilation may well take the place of " automatic " air exhaustion.

The claims of so-called natural ventilation should, however, be well considered. The system is by no means put out of court by the fan method of ventilation. Natural ventilating devices have been much advanced in this country by the persistent efforts of specialist firms, who have gradually evolved certain forms of static apparatus, tending to take advantage of the fact that the air in apartments is ordinarily at a higher temperature than externally, and that it is a fact that even in a cold boiler stack there is a powerful up-draught. Natural ventilation, therefore, as contrasted to mechanical, is as the chimney to forced draught. Not altogether so, since the rarity of the products of combustion, as against the atmosphere, makes the action more pronounced and definite.

One of the common objects over large roofs is the ventilating cowl, or static air-pump, showing that in practice natural ventilating methods have many adherents. All such apparatus depend on one principle—that air blown horizontally over a vertical shaft causes tendency to vacuum in the shaft and a resultant continuous up-current. The devices employed, of certain inclination and arrangement of louvres and blades, tend to enhance this action.

A very common arrangement comprises such a static exhauster sitting on the roof ridge and connected by ducts in the roof to grids at ceiling level. The theory here has an evident defect—the wind force varies, therefore the up-draught, or air-suction power, must vary. There is no denying this; but at the same time the great number of buildings fitted with this system suggest that what may appear an objection in theory is not bound to be so in practice. In suitable cases it is found to be all that is required. Libraries and other apartments sparsely occupied by persons in health seem quite well ventilated by the so-called natural method. For combining with heating, the ventilating radiator, or system where air is admitted and tempered near to radiators, seems the most satisfactory.

But the main underlying principle requires to be observed. Hence exposed radiators giving an up-current are better suited than any kind of indirect heating methods. Nothing could be better suited for small "cottage" hospital wards, ordinarily having a very few occupants to a large cubical space. This is the best case for natural ventilation, just as the plenum, or air-forcing system finds its most useful field where the occupants are many and space restricted; as theatres, where, although a number of such still take advantage of the heated body of air from gas and the raised domical ceiling to rely on natural means of ventilation, as a general rule, and especially in these times of electric lighting, the theatre is a most fitting place for forcing in warmed air. This is generally accomplished by an elaborate system of ducts at a low level.

Sufficient has been said on ventilation to show that the question of the best methods of air supply to institutional halls and apartments, and generally in public buildings, depends primarily on a minute investigation of local and particular circumstance and conditions, and not upon formulæ. The engineer must exercise his own wits—clamber up the futtock shrouds, not sidle through the lubber's hole. Where ducts and tubes connected to vertical shafts satisfy conditions, a fan is superfluous; where the maintenance of constant air-flow is paramount, the fan becomes a necessity, although something may be accomplished with hot bodies, as gas-jets or radiators, in vertical exhaust shafts, to add vigour to sluggish so-called natural methods. An extremely useful exhauster is the common chimney flue, and if this is 14 inches square, in place of the more usual 9-inch, a large number of cubic feet of air are drawn up hourly. This action is wholly independent of the fire in the grate, although that naturally aggrandises the effect. Why this is so is not altogether apparent, but the fact that there is a powerful up-draught up tall chimneys must be considered a strong "bull point" for the natural ventilationist.

The heated bodies in vertical shafts above referred to are not very effective. In the boiler chimney the gases may, and usually do, enter at about 600° Fahr. as an economical temperature. The small amount of heat given by gas jets and radiators bears no comparison to this. It is suggested by this that dependence should be either on so-called natural methods purely, or upon the positive draught system of rotating fans. Of these there are in the market, displacing fans with blades and forcing fans with centrifugal action. The greatest call is for the former, but for large air supply the centrifugal action is more economical of power. The most useful data have been established by experimenting in mine ventilation. The practical deductions have been: relatively slow fan movement and smooth flue walls with easy bends. The mathematical points are the efficiency of fans of definite shape at given speeds, the suitable cross-section of ducts and

proportioning of branches to the various services, facts readily accessible in many text books. A recent German example is, as usual, an array of figures. It also contains a "scheme of exhaust heating," where, instead of taking a steam-pipe direct from boiler to engine, this crosses and recrosses the whole plan to meet the convenience of a certain live-steam distributing main; but we must remember that it was a profound philosopher who made the big hole for the cat and the small hole for the kitten.

The persistence of the 1911 "heat wave" caused considerable inconvenience in public institutions. Ideas during that period must have tended rather to cooling and ventilation than to the warming of buildings. The author addressed letters to many medical superintendents of hospitals and asylums. A concensus of opinion seemed to exist that, if means were available for maintaining a lower temperature, during excessively hot weather, in wards, etc., the comfort at least of patients, inmates and staff would be considerably enhanced. Many held that the welfare of patients would be promoted, and that the excessive heat had prejudiced recovery and progress. This seems especially so in consumption hospitals, in the case of patients confined to bed, and also in hospitals dealing with nervous complaints and affections of the heart.

The correspondence indisputably proved that the subject of building-cooling has been neglected. The reason is sufficiently obvious—the rarity of sustained high temperatures in this country. Were we assured that a sequence of hot summers, such as that of 1911, were to be anticipated, serious attention should be given to this matter. Simple devices as a stand-by—for emergency—are justifiable provisions in hospitals, asylums and the like; but, say, at least one especial ward for critical and sensitive cases should be included in institution buildings. The principles to observe in making such provision may be either cold "radiation" or cold air supply. In America considerable use is made of genuine refrigerating machinery, mostly on the ammonia-compression system—brine being pumped through cooling pipe-coils in the several rooms. For serious building-cooling, actual refrigerating machinery and brine circulation seem requisite. Much could be done temporarily; and ingenious charge-engineers, by slight modification of existing heating pipes, could adapt a small refrigerating plant to circulate brine through radiators; providing stop-valves, by-passes, etc., in the existing circuit of pipes to this end. It requires to be observed that unless there is forced circulation of brine or ice-cold water by pumps, the arrangement must be inversely as with heating installations. The freshly cooled brine will fall and displace that which has acquired warmth by absorbing heat units from the air. In the three diagrams in Fig. 43, the upper one represents a building having a "boiler," B, hot-water radiators, R, and ordinary flow and return pipes; the circulation is as

indicated by the arrows. If we wish to arrange a cooling system for the building, and conceive that the existing radiators may be kept full of brine, and desire a natural circulation—i.e. without a forcing-pump—then the source of cold or brine tank must be placed above, as indicated in the intermediate diagram at C, and the circulation will be as shown by the arrows. It would appear from these considerations that a system could be installed as indicated in the lower diagram, whereby, by simple by-pass and stop-valves at P, the radiators could be supplied with hot water in the winter and brine in the summer. Very compact refrigerating plant is now in the market, and may be conveniently motor-driven. The idea here generally discussed may be suggestive to charge-engineers, in making alterations to existing piping, etc., to meet the requirements of medical superintendents in exceptionally hot weather.

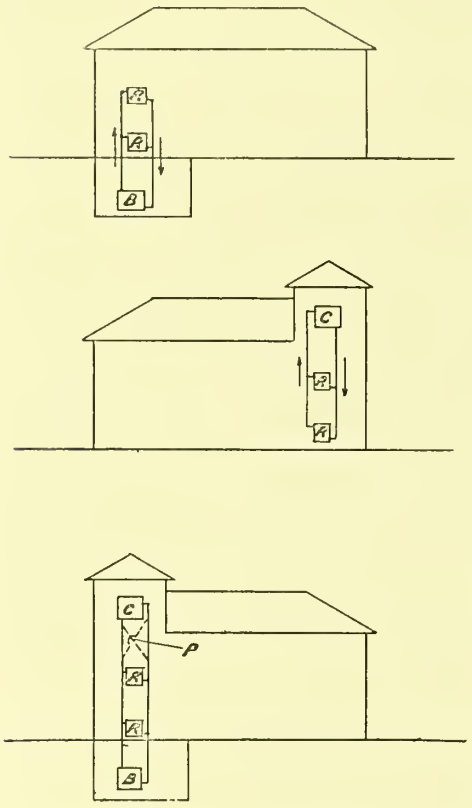


FIG. 43.—DIAGRAM OF BUILDING COOLING.

The same general principle—the superior gravity of cold liquids and gases—must be remembered in any scheme for supplying cool air to wards. It is rather against the temporary measures suggested, that cold "radiators" should be at a high level. Such at least seems a reasonable assumption, and supported by the procedure of refrigerating engineers in cold storage work. A consideration of facts and conditions suggest that, in a ward, the source of cooling should be near the ceiling and running centrally down the axis of the apartment, and this seems a correct conclusion, whether we think of a cold air supply or so-called cold radiation. Cooled air would drop vertically, and spread out towards the side walls. The side walls being heated by the sun's rays would cause an up-current. This suggests foul air extraction at the ceiling over the window heads, led away by shafts and ducts in the roof to automatic extractor ventilators. If these premises are correct, air cooling is a great help and promotes the vigour of what is called natural ventilation. The heat of the roof and the heat of the extractor ventilator, exposed to the sun, would all help the air circulation, on the principle that the cold air would fall and displace upwards the heated air. Providing means of catching condensation, a practical and thorough way of cooling a special

hospital ward would therefore be with a refrigerating machine, brine circulation in a special pipe-coil along the axis of the ward, and air abstraction by ducts along the ceiling next the side walls. The general idea resembles arrangements in attemperator rooms in breweries where in the heat of summer a cool October temperature may be obtained.

In the case of cold radiation on the plan suggested, as distinct from cold air supply, fresh air might be admitted over the fanlights common in hospital ward windows.

The objection to ice-boxes, open water-tanks, to washing internal wall-surfaces, and to passing air through water spray and water screens, is that all such cooling by evaporation effected inside the apartment, or in chambers connected to such apartment, necessarily adds moisture to the atmosphere of the room. Air can sustain moisture in proportion to its rise in temperature. The most oppressive days are those with a high degree of humidity in the air. To get rid of the moisture the dew-point must be lowered, and, by passing air through brine-cooled pipes, moisture would be thrown down. In this way something seems possible in the way of arranging on a damp, hot summer's day, an approach to an Alpine climate for sufferers from consumption.

At first sight the great evil is the hot wall. In the sun's rays during the day the bricks absorb caloric, and radiate this at night. Many thousands compelled to sleep in bedrooms unprotected against heat-absorption during abnormal summers, know what this means. On the other hand, it is extremely probable that this store of day-heat is a safeguard against worse evil. This at least may apply to private individuals. In medically-supervised institutions, it might be well to pay more attention to the construction of hospital ward walls—that they may be in some measure insulated both against excessive heat and excessive cold. Underground apartments, caves and thick and cavity-wall buildings are cool in hot weather by virtue of their insulation.

CHAPTER XII.

WATER SUPPLY.

The first cost of a complete engineering plant for public institutions is considerably lessened where water is taken directly from the water authority or company; but running expenses may be heavily increased. It has been said that the average cost of raising water from private wells is from $2\frac{1}{2}d.$ to $3d.$ per thousand gallons, and this includes, in favourable instances, interest on capital and other fine matters of expert accountancy. The economy is, therefore, very considerable where private wells and pumps are installed. Owing to the method of charging commercial undertakings instigated by the Metropolitan Water Board, the last year or two has seen large numbers of private artesian wells bored in the London basin for hotels, offices, and works.

Well-boring has been reduced to a fine art by experienced and specialist firms, and failures are now rare, although among inexperienced ventures the number of fiascos is surprising. Well-boring operations, when conducted in cramped positions (as in existing buildings) require considerable resourcefulness. The operation in the open looks simple enough, and this is how, possibly, the unwary are misled. The plant for "percussion" boring, such as prevails in the London basin and districts having similar geological characteristics, is inexpensive. A small steam boiler and a winch, a rough derrick and a few simple chisels and shell tools comprise the main equipment, and possibly, as a consequence, a fair amount of what may be styled amateur work is done, or commenced, leaving the position finally that an experienced firm is called in to remedy, if possible, an egregious bungle. The moral for consulting engineers and architects is to limit tenders to experienced specialist firms, and to be not above taking all their hardly-gained practical hints in all questions at issue. Well-boring, lining, and deep-well pumps should come into sub-contracts, whatever else may be included in main agreements or thrown open to public competition. All goes as it should for the first hundred feet or so, but a hole may get finally in winding, and everything become hopelessly stuck, requiring much ingenuity to pull out the old tubes and re-establish axial truth in the bore, if, happily, such result be possible. Again, in London boring, an essential point is the junction of the lining tube and

chalk—the water-bearing medium—and it is to be assumed that there have been occasions where, instead of tapping (as supposed) an abnormal and impure supply, what has happened is that surface water has penetrated into the well. Only on this assumption can some of the unfortunate well-boring results be explained.

The artesian system most generally meets the requirements of institutional engineering. In genuine waterworks the chief resource of engineers is sinking, and of large diameter, down to such depths as will enable the pump, in all its parts, to be accessible ; that is to say, to a point where the natural water standing-level will rise, leaving a free, get-at-able suction-pipe and strainer. This is a necessary or, at any rate, a desirable procedure in important undertakings, although the hidden deep-well barrel and bucket seem reliable enough. But the practice of sinking wells, and exposing all parts of the pump mechanism, facilitates inspection and repair. In waterworks practice, the main use of artesian boring is for making increased collecting area. The collecting area of a bore-hole is the circumference × length below standing water level. This can only be increased in a haphazard manner by shot-firing, a recourse unusual in chalk, and mainly confined to rock strata. It can be seen from this that, as in the chalk wells of Kent, considerable advantage may attend plain sinking with adit driving, as against boring vertically. Neglecting adits, the collecting area of a 10-foot sinking, 25 feet deep, is approximately 775 feet super., requiring a bore-hole of 1 foot diameter, to be carried down some 258 feet to give an equivalent potential collection. No doubt the effectiveness of adit driving in suitable water-bearing strata is frequently a determinant in matters of boring *v.* sinking, and for all reasonably large water-undertakings wells are sunk. Which of the two courses, boring or sinking, should be adopted in institutional engineering is a matter dependent on size and situation of the establishment for which water is required. The geological characteristics must largely enter the question. If the number of gallons per day required is small, it would point to boring ; where a large institution might be better suited with triple-barrel pumps in a sunk well, continued possibly with a bore-hole for collecting, a very common practice nowadays.

It must be assumed that many engineers are prejudiced against deep-well pumps where a straightforward course would have been boring. The first impression is certainly against putting a piece of machinery hundreds of feet down a small bore. Yet it has been shown that in practice, with proper appliances, and space and arrangements generally made for convenient and periodical uphauling of pump rods, etc., for inspection and repair, the trouble is imaginary. The artesian system saves money and space. It may often cause less trouble, in carrying through difficult sands, where the lowering of cast-iron drum linings may encounter difficulty.

The largest class of public institution is now on such a colossal scale that the water requirements approximate to those of a small town, and in these cases the sunk well and triple-barrel system is indicated as reasonable, and the same may be said of the largest class of hotel and of the outsize of public bathhouses ; but to decide upon the best means of providing water supply one needs to know the size of institution and the likelihood of its being enlarged in the near future, the neighbourhood, and its geological features. Much information on this point may be gained at the Geological Museum, and this, together with local opinion

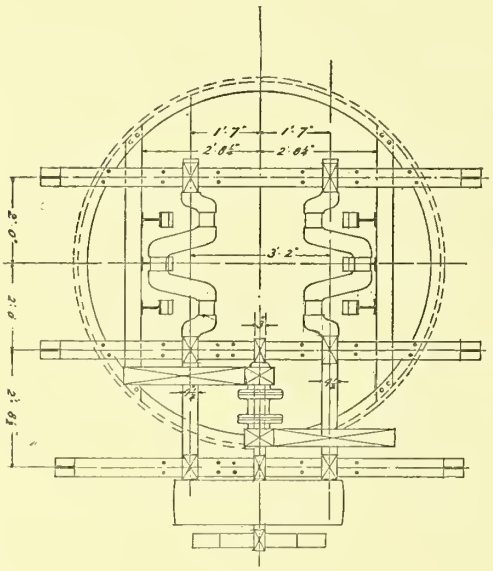


Fig. 44.—Savoy Hotel, London, Well Gear : Plan.

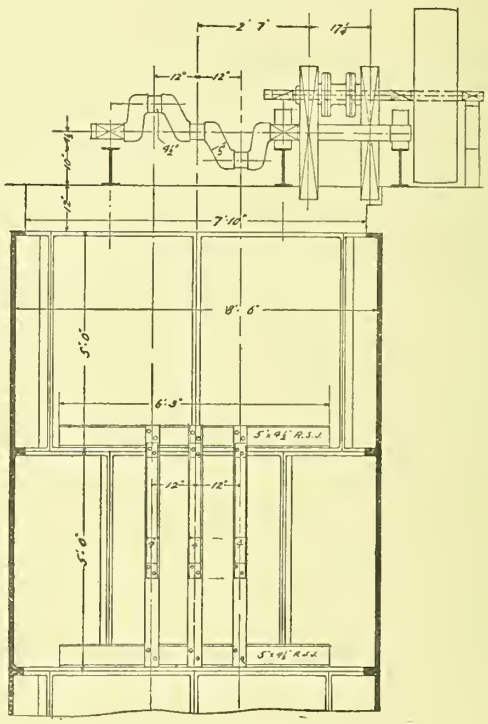


Fig. 45.—Savoy Hotel, London, Well Gear : Section.

and the collected data (from works executed) of the well-boring profession, may enable conclusions to be made whereby, with the exercise of that care and forethought which is a first requisite in water-getting proposals, a hopeful commencement may be made on a definite plan, leaving perhaps till the time of testing the question of carrying bore-holes deeper to gain a more abundant supply.

The modern sunk well has bolted cast-iron lining, with suitable backing ; the artesian bore is lined with screwed and socketted steel tubing, which in the London district is driven hard into the chalk bed. A small sumphead is the practice with artesian bores, wherein may be located the upper part of the pump

and gear. Bore-holes up to 12 inches diameter of liner tube may be considered usual and common.

Large bores are not frequently made, possibly for the reason that with a little increase in diameter of well a small average sinking width of 4 feet 6 inches to 5 feet is attained, and sinking operations may be substituted, permitting the installation of visible and accessible pumping gear complete; and also for the reason that, say, two 12-inch wells may be more convenient and practical in working than one of an outsize of bore.

Large bores require heavy tackle, etc., and the increase in cost is not in arithmetical proportion. Two 10-inch diameter rising mains in 12-inch liner tubes both normally worked, but the duty capable, at a pinch, of being fulfilled by one pump, is a useful arrangement in an average institution. The arrangement enables repairs and inspection to be performed, and should, by any chance, the water standing-level fall back at any time, the supply will not greatly suffer by some weeks expended in deepening bores—a very common expedient for getting a better supply.

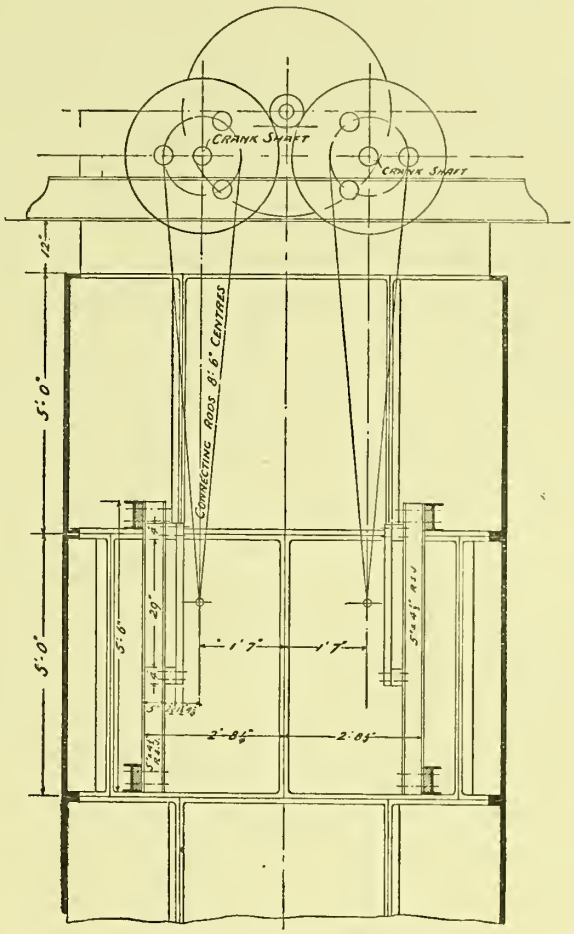


FIG. 46.—SAVOY HOTEL, LONDON, WELL GEAR: SECTION.

Having decided upon a type of well and suitable size, and a pump that at a certain number of strokes per minute will give the required number of gallons supply, working at convenient times daily, it is necessary to provide suitable prime or secondary mover for the power. The calculation of net horse-power required is the simplest exposition of the foot-pound system of estimating dynamic energy; the gross amount requires the addition of an allowance for frictional resistance both in water flow and in rods, levers, etc., and the practice in small plants is one-third the net estimate, the result being the required brake horse-power. As a prime mover either steam, gas, or petroleum engines are nowadays

largely employed, and, as secondary, electrical motors. It is not desirable to jump to the conclusion that the electric motor is the best.

In institutions the necessity for heating together with the necessity for power introduces steam as a further necessity. Steam, once introduced, is the chief and only medium of heating—by water indirectly perhaps. It results that in all cases the steam required to be generated greatly exceeds that required for power. The obvious indication is that where further power is required let the steam exercise pressure on pistons before going to heating duty. The idea here is, for institutional engineers, quite foundational; so much energy must go in electric lighting, and possibly here and there a small electric motor may be a great and special convenience; but assuming a considerable power duty to be superimposed on the lighting—as, say, water-pumping—to pass along live steam to calorifiers and use motors for wells is not rational. Let a steam engine be interposed between the boilers and the calorifiers, and the amount of heat taken from the steam is fractional. In truth, this is but another way of saying that steam engine exhaust should be used for heating, but it is putting the matter in a sidelight, and one that illuminates the question of power for water raising. At first sight the use of steam for pumping with direct-acting pumps suggests great waste, and if all exhaust went to atmosphere, or in cases where building-heating is not a factor, and as concerns power station work and the like, the question of motor pumps is necessarily to be considered; but, even assuming the adoption of the extremely slow-moving direct-acting pumping engine, it remains that whether 60 lb. or 160 lb. steam per horse-power hour is required, if there is an engine introduced into the steam-heating cycle, and the heating duty is far in excess of power requirements, it matters little exactly what steam passes through the engine, the only point needing attention being that the whole steam required for engines shall not exceed that required for building-heating.

As the conditions hereabove generally assumed are such as rule in most large modern public institutions, it results that steam is usually the correct medium for producing power for institutional water raising. It is convenience alone that may negative this as a general conclusion.

The simplest form of deep-well pump comprises practically a piston at the end of the pump rod. The extremely slow reciprocating motion required for the effective operation of water raising by bucket and plunger suggests a most wasteful form of prime mover. We have seen that for institutional work such a large volume of steam passing through the cylinders may not necessarily be objectionable, and this may be so in spite of the heavy intra-cylinder condensation. The engine simply stands as a by-pass or branch supply-pipe between boilers and calorifiers. Such engines have simple slide valves, and correspond to vertical feed

pumps with greatly elongated pump-rods. Bolted to a couple of rolled joists over the well sump pit, a very simple pumping device is provided.

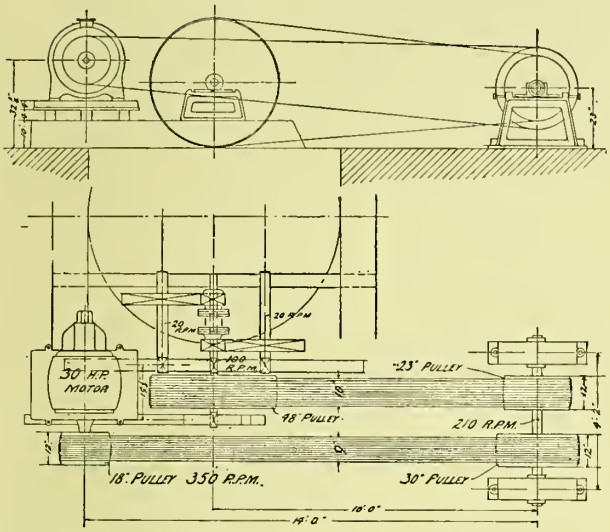
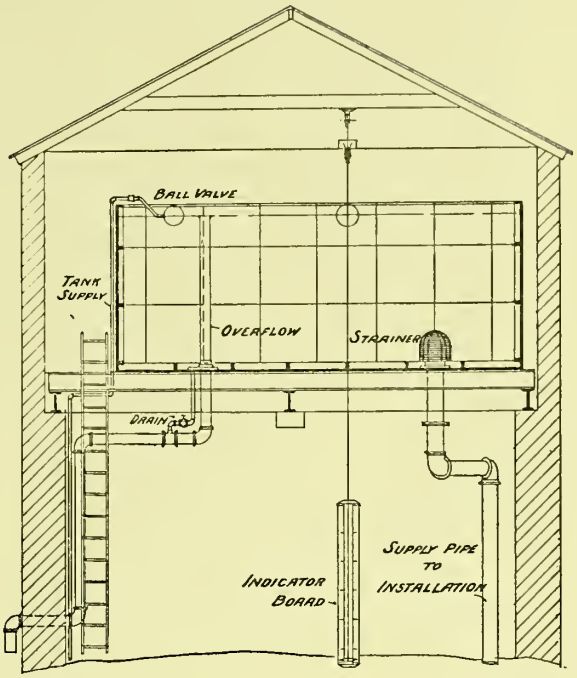


FIG. 47.—SAVOY HOTEL, LONDON: ELECTRIC DRIVE TO NEW WELL.



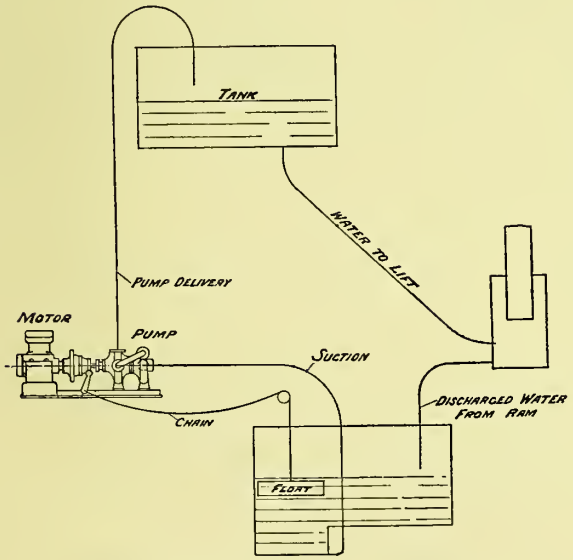


FIG. 49.—AUTO-CONTROL OF PUMP.

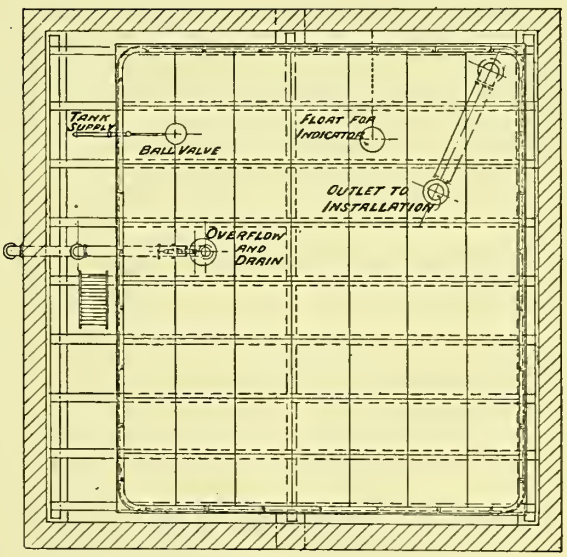


FIG. 48.—CAST-IRON WATER TANK.

Where pumping has to be provided without the accompanying building-heating by exhaust steam, the question of engine assumes a different aspect,

albeit that the duty performed by old Cornish direct-acting waterworks engines, with smart cut-off, is a matter of surprise. The modern waterworks engineer favours high piston speed, and gears down his pump, as in the example at the not long built Ilford Pumping Station, where the gearing down is three to one; a beam actuates bell-crank levers, with two balancing pump-rods, the pumps lifting only, the forcing pumps being below the engine directly actuated from the cross-heads. A common arrangement in many existing institutions comprises belt drive at suitable pulley-diameter ratio, from an ordinary type of horizontal steam engine, the pumps generally triple-barrel, with three-throw crank shaft and long pump rods passing down the sunk well. Many gas and petroleum engines are thus coupled to well pumps, both of triple-barrel and deep well types, but only quite exceptional circumstances or unusual ideas on the part of the

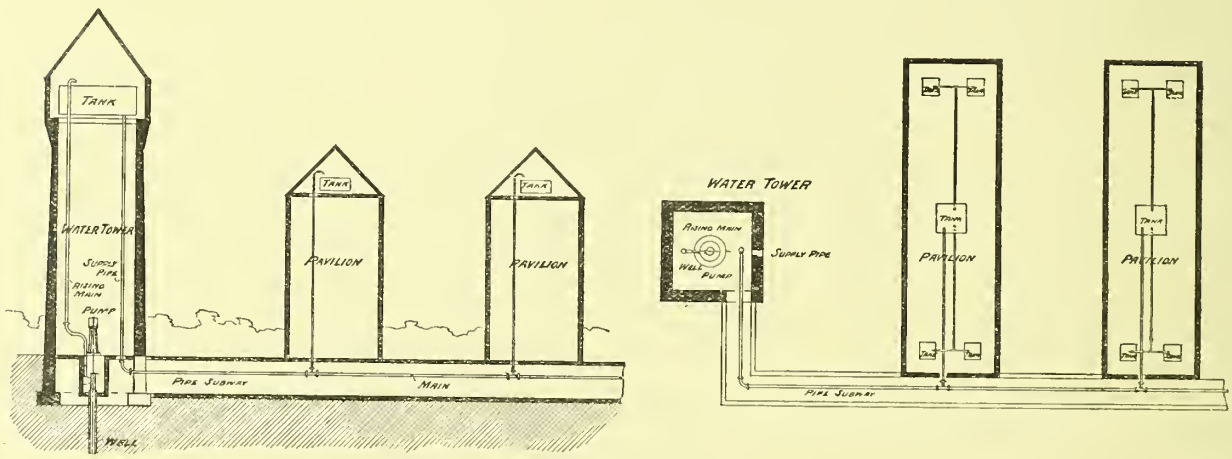


FIG. 50.—WATER-TOWER: SECTION AND PLAN.

engineer will introduce internal combustion engines, where building-heating is required.

The best electic drives have worm-gear reduction; the motion direct-coupled to worm and the worm-wheel, with single or mutiple gearing, connected to the triple-barrel pump shaft. The same worm-wheel drive is suited for operating deep-well pumps proper, and has been much adopted in city office work, where silent action is desirable.

An ordinary form of single-bucket artesian well-head gear comprises a counterweight to balance the weight of pump rod. A sump is constructed at the head of the boring. At the floor of the sump, which may be concreted, appears six inches or so of the uppermost lining tube. A couple of steel joists, are laid across the sump coping, and from these depend the whole weight of

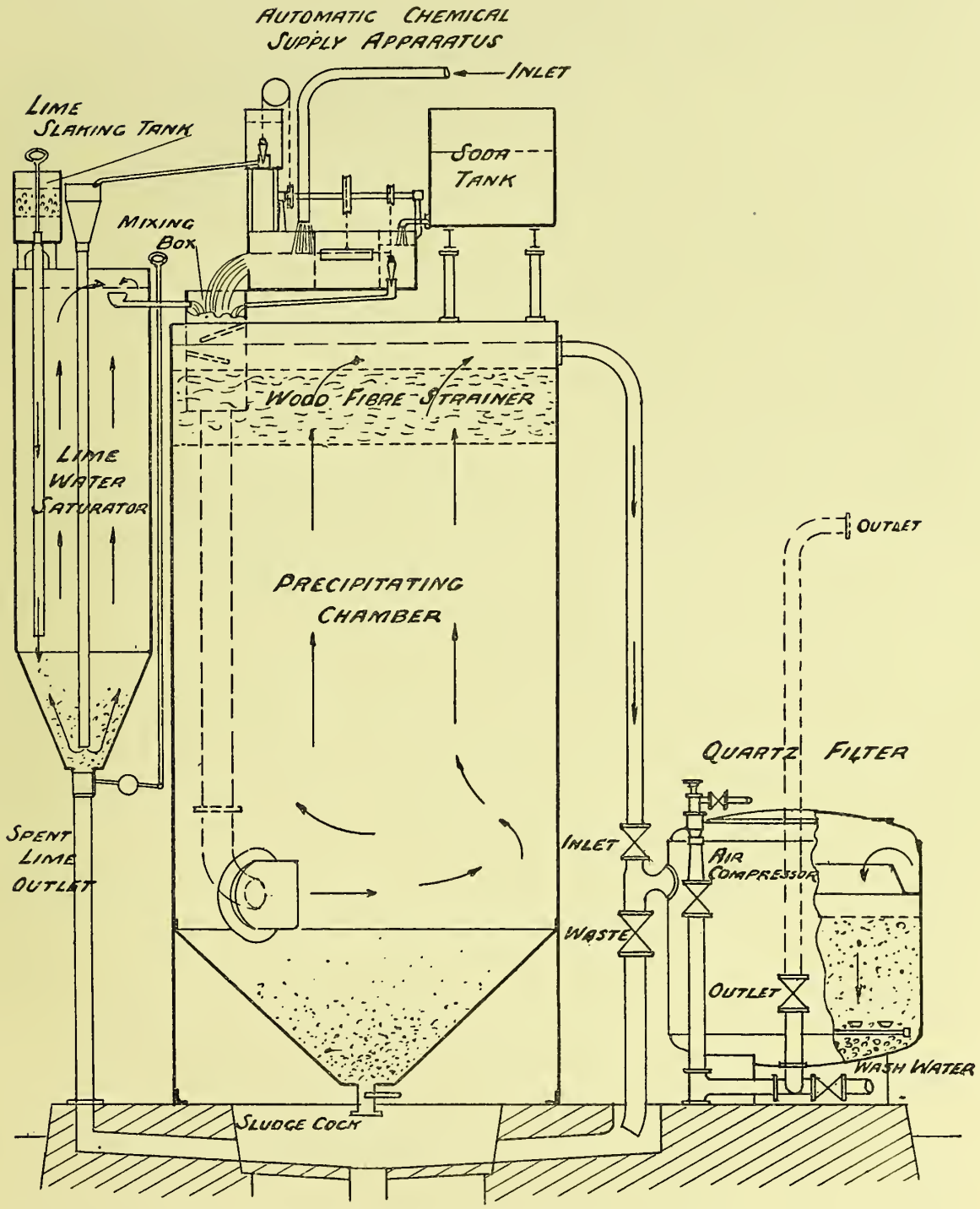


FIG. 51.—COLD PROCESS WATER SOFTENER, WITH FILTER.

the complete rising main, having at its liner end barrel and suction pipe, all much as roughly sketched in Fig. 1.

The pump rods connect to a slipper in slides with cross-head, connecting rod and big end to crank shaft. The latter has a crank-pin in a disc end, and from a second connecting rod, slipper and cross-head depends the counter-weight adjusted to balance the whole gear.

The author has to thank Mr. Reeve Smith, the managing director of the Savoy Hotel Limited, for permission to publish the accompanying useful drawings, Figs. 44, 45, 46 and 47, of the gearing and electrical drive of the new well at the Savoy. The well was sunk by Mr. Richard Batchelor, and completed from the designs and under the supervision of Mr. Harold Hale, the chief engineer of the Savoy Hotel.

We have seen that in providing water for institutional buildings and the like, there is needed either a sunk or bored well, or a combination of these methods, either large, single, or mutiple small bores, all absolutely dependent on the type, size, and locality of the buildings. To raise the water we have considered that in the majority of cases steam engines are most suitable where steam is raised for heating and where any power at all is required, and it might here be added that where electrical energy is purchased from outside the indications are more in favour of electrical well-gear and pump drive.

Assuming the water found and brought to the surface, it must be raised to a height giving a suitable head for use. The water-tower is an everyday feature of most large institutions, and is ordinarily a lofty brick-built structure, rendered decently architectural, with proper roof often, and at times having incorporated a boiler stack, the construction of such being by no means necessarily displeasing architecturally, a gain in economy (saving brickwork), and presenting no practical objection where an effective fire-brick lining is provided well up in the vertical flue; indeed some of the essays at combined tower and stack must be adjudged of positive æsthetic merit, on a plane at any rate. The height of the water-level in tanks must be decided by suitable feet-head increased by allowance for frictional losses, to the end that there may be a pressure at draw-off taps suited to the working of baths, lavatories, sinks, kitchen, laundry, etc. No account need be taken of fire service, it being more usual to have special fire pumps quickly started and regularly tested at short periods, whereby either an independent suitable pressure may be established or the normal main service pipe pressure boosted on such a system as on the plan before given—Fig. 28. The extra fire pressure is conveyed in special fire mains, having hydrants at suitable points round about and in the institutional buildings. An efficient fire service is evidently of vital importance. In large cities the fire brigade, with its effective apparatus, is

on the scene in a few minutes; but large institutions, having a thousand or more of inhabitants, are frequently erected in quite secluded country sites, and the whole are at hazard if left to the village fire brigade. The modern institutional fire service should, therefore, be complete. In some schemes there is reliance on town's supply pressure, but more properly there is a special pump, either steam or motor driven, and in this case a motor drive is indicated, such being instantaneous in starting, and starting at full efficiency. The whole is kept ready for prompt action by tests and practice, made at short periodic intervals. The question of water-tower height, therefore, is not ordinarily controlled by the question of fire service, excepting in so far as to give an adequate supply to the fire pumps, and perhaps a pressure that can be suitably aggrandised.

It is assumed a principle in public baths engineering to give an equal pressure to both hot and cold water supplies, leading to convenience at operating bath valves. This is naturally brought about by making the usual connection of hot supply to cold, bringing the whole into equilibrium. The same rule holds in institutional water engineering, as, indeed, in every domestic installation. Too small a head is a nuisance; too much pressure unnecessary, and likely to add to valve troubles. A pressure of, say, 30 lb. per square inch corresponding to a head of about 70 feet, plus what allowance may be made for frictional loss, is suitable for the average institution, leading to a ridge height for the roofed water-tower of, say, from 80 to 90 feet, and allowing an average suitable height for the ordinary institutional boiler stack, of say 120 feet, this feature may run boldly clear of the tower roof peak. The remarks made assume the ground floor as datum line, and a lower pressure for the several superimposed floors, inasmuch as these may be three or four in number, as in wards of ward pavilions.

A usual recourse is to carry by brick tower walls and steel joists, a cast-iron, machine flanged, bolted and stayed water-tank, with all the customary fittings for supply, overflow, and a convenient indicator gauge. Fig. 48 is an example of such a water-tank by Messrs. Mather and Platt, Ltd. The tank is only an accumulator, and not, strictly speaking, for storage as such, it being assumed that the well pump can be put in operation at all times. Practically, however, a generous size is usually provided, and that size in any given case must be dependent on the size and nature of the institution, convenient times for pump operation, etc. Auto-arrangements for starting pump motors on water-level falling to a minimum can easily be installed. Fig. 49 is an interesting example by the Aster Engineering Company Ltd., with motor and clutch, for the Houses of Parliament, Constantinople. In and around London our assumed water-tower height means about a total of 300 feet head against the well pumping engines, or a net expenditure of 3,000,000 ft.-lb. of energy for every 1,000 gallons raised

to tank. Water-lifting in quantities to considerable height is somewhat expensive, and economy is desirable in pumping arrangements.

Water for hydraulic duty (lifts) is provided by special pumps, and where electric motors, auto-controlled, are desirable, and on general grounds choice-

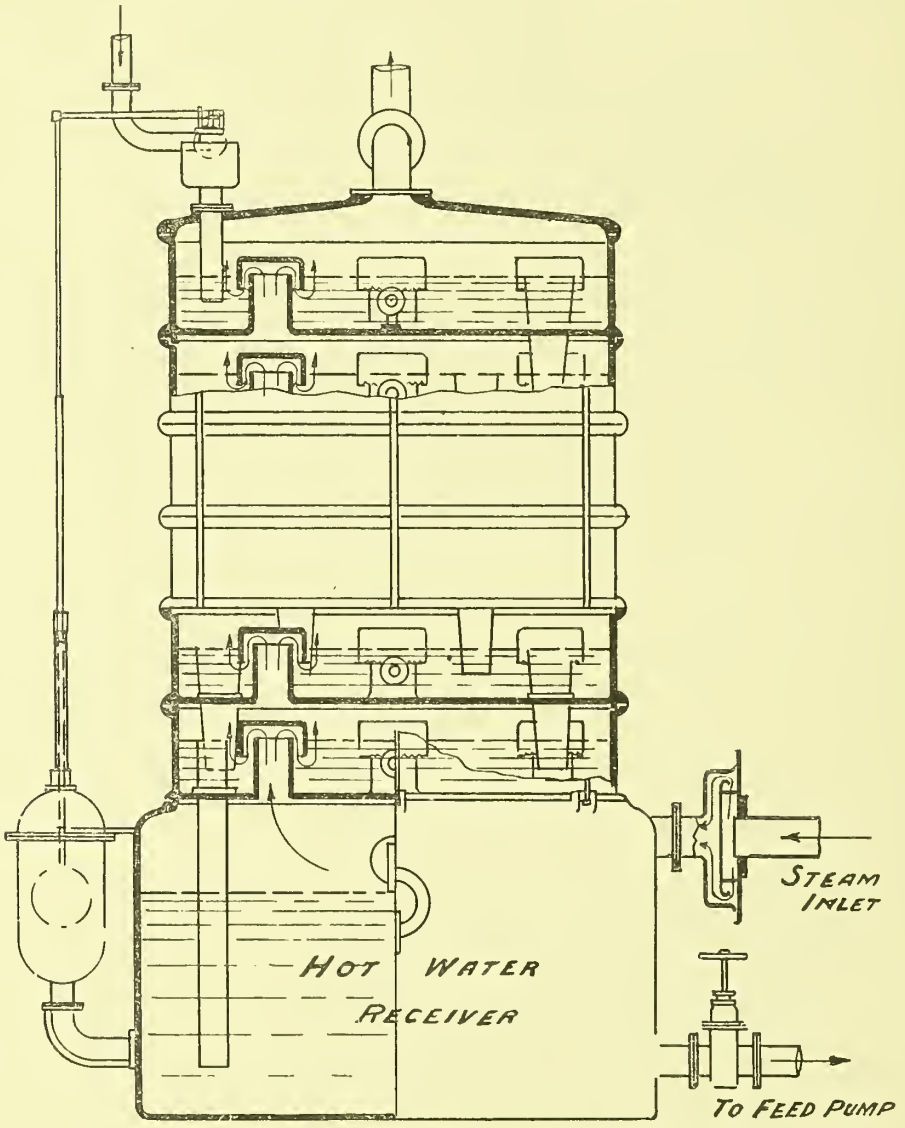


FIG. 52.—HOT PROCESS WATER SOFTENER.

worthy for country institutions, control devices for stopping and starting by users, have of late been much improved by specialist firms.

From the considerations made it will be seen that in the water-tower will be one rising main (from pumps) and one descending supply pipe, which pipe will

serve the local cold tanks and the hot-water services, and, indirectly, the fire service and any hydraulic plant. These pipes may at times be run in duplicate, but without any very logical reason, other than nervous mistrust on the part of the designer. The water-using and water-controlling devices in the institution are ordinarily connected not to this supply, but to local tanks at convenient points, as in the diagram Fig. 50. The cold water main will connect to calorifiers for supply, and from thence will commence various branches, similarly, to points needing hot-water supply. It will connect to hydraulic and fire service as explained. The whole piping running in subways in large buildings are, one or other, of steam, condensation, cold water, fire, or hydraulic. Cast-iron has been largely used for all services, including steam where under 100 lb. per square inch, and for water in old installations, ordinary spigotted pipes; but modern tendencies obliterate these for all services. Flanging adds to first cost, but the convenience in addition and repair is great. Cold drawn weldless piping deserves more attention.

Every large institution will do well to collect its roof rainwaters. Such water is soft, and may be stored in tanks and connected to engineer's block by suitable pumps. One of the perennial troubles of institutional engineers is hardness of water. The trouble is evidenced in boiler scale and similar deposits in supply calorifiers, especially if these latter are permitted to attain to more than some 175° of temperature. The water softener is in evidence in most engineering departments, either the cold lime process or the detartariser. Either exhaust or live steam can be used; and that such appliances take little ground space may be observed from the plan heretofore given (Fig. 22 and 23) of the boiler-house at Peterborough Waterworks. The fundamental principle is to heat up water outside the boiler to a temperature approaching boiling point, with the result that scale is precipitated outside instead of inside the boiler. The high pressures ruling in modern engineering practice demand more careful attention to the degree of hardness of feed-water. And in this respect it is shown that shell boilers nowadays require as much care as other types, as has been pointed out by Mr. Michael Longridge, whose report is quoted in Chapter VII. Fig. 51 is a drawing of a cold process water softener by the Patterson Engineering Company, Ltd., and Fig. 52 a detartariser by Messrs. Booby.

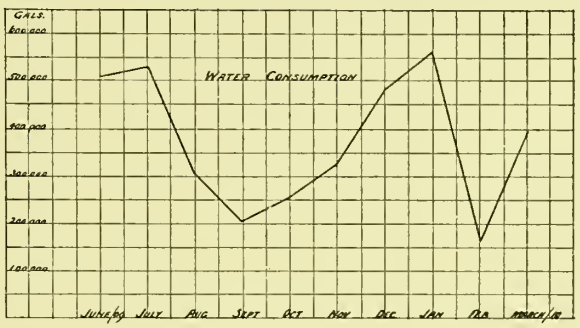


FIG. 53.—CURVE OF WATER CONSUMPTION.

Water softening is applied solely to boiler feed—as a rule, at any rate. The

matter is important here, but, if not of importance on the same plane, the evil is evidenced more than anywhere in water-supply calorifiers. It is a common thing to hear of these appliances being completely furred-up, a solid mass of scale. This is not picturesque hyperbole. The evil arises from three causes in combination: (1) The nature of water; (2) the ways of the manufacturer; and (3) the ignorance or neglect of attendants.

The building-heating calorifier causes no trouble; the same, or practically the same, water circulates week after week, and once softened remains so. Hence, any kind of design almost is suited for the duty, and efficiency of tube and general design may rule. For the supply heater, fresh water continually enters, and very careful design is necessary. Makers should not sacrifice everything to efficiency for size and cost of appliance. A common error, or wrongful act, is to pack together the tubes with only a quarter of an inch separating them. This may do well enough for building-heating. When used for supply purposes deposit gradually accumulates until, as we have seen, it is no exaggeration to say that they become solid scale throughout. Even allowing that the deposit must go on, proper design would alter the position. The scale at first forms a slight film round the tubes—the steam being assumed to be inside—and at first nothing results but loss of efficiency in heat transference. In progress of time this film increases in thickness, and a certain thickness is reached where the unequal expansion of scale and metal causes the former to crack. If the tubes were but reasonably far apart the scale may then drop to the bottom of the calorifier casing, and no great harm result from its presence until clearing-out time. Such a calorifier is sold for its heating efficiency for size and prime cost, but it is not what the institutional engineer wants, as he finds out later.

The errors of the attendant are in allowing the hot water to attain an unnecessarily high temperature. By so doing he converts the heater into a kind of detartarising water softener. About 180° Fahr. seems the crucial temperature at which the lime substance will commence to precipitate and the temperature is quite unnecessary with vigorous circulation and proper mains, while the auto-control devices have been highly recommended by engineers qualified to express an opinion; and it would seem that, providing regular attention to such, they may be relied upon to shut off steam within a very few degrees of the maximum temperature desired, which may be 175°, rather less than more.

A water-supply calorifier should, therefore, have ample distance between tubes, tubes of a form easily cleaned, and automatic regulation of water temperature.

Fig. 53 is a curve, showing actual water consumption at a London infirmary.

CHAPTER XIII.

INSTITUTIONAL BATHS.

Bath work, in institutional buildings, is mainly confined to fitting up ordinary slipper baths. The bathing accommodation in hospitals is almost entirely of this type. Institutional bath engineering (so far as concerns the engineer) is, therefore, little more than an extension of the general idea in domestic work; that is to say, the ordinary hospital ward bath is simply a suitable, modern house bath, but with most advanced ideas as to fitting, the demands of hygiene and cleanliness in working and invention are directed to ensuring safety in use. Special hospitals provide special bathing appliances; according as to whether the ideas of the medical superintendent incline towards hydropathy as an aid to established allopathic principles as fundamental basis, so more or less varied forms of local bathing appliances may be installed. Such matters hardly affect the engineer, and are more strictly architects' business. All the engineer is concerned with is the provision of correctly-working supplies of water, hot and cold, and his chief anxiety should be, in a sense, that of the electrical charge-engineer—to keep, so to speak, the line "alive." The introduction of a small pump into the hot-water supply circuit may be as beneficial as it proves for building-heating. An example of the use of this was given in Figs. 4 and 5. The arrangement shown is fully justified, inasmuch as a large and ramifying pipe system necessarily exists in water supply for large hotels, whereas the kitchens, being close to the kitchen calorifier, suitably generous pipe arrangement and diameters with a genuine flow and return render a pump superfluous. In Fig. 32 a block plan showed the forced hot-water system at Camberwell, the calorifier pump connection being given in Fig. 39. There is a tendency, and a wholesome one, to put these circulating pumps in public bath-houses. Many of the older public baths had not even a gravity flow and return. This worked well during busy hours, but, especially in the mornings, inconvenience was found. An improvement was the addition of flow and return, or at least of a small return to keep movement in the water; but in most large buildings a suitable forcing pump is good practice. The system should be, for public baths, a lively flow in mains and main branches, short connecting pipes to baths, etc., without returns, presenting no objectionable feature. Much depends

on the shape and arrangement of the building in this matter, suitable cases enabling gravity circulation to well meet all demands. It is to be noted that a common complaint of the superintendents of public baths is that the arrangements provided do not give sufficient hot-water storage, and this point is met by connecting a roomy dish-ended cylinder with flow and return to calorifier. This then acts as an accumulator, and prevents the evils attendant upon all kinds of working without power in reserve.

The modern public bath-house is an interesting example of building-engineering, to use a suitable term. It is outside that which one understands by institutional engineering, but a knowledge of the most up-to-date arrangements in such establishments is useful, and in some institutions a swimming-bath is required. A rough diagram (Figs. 8 and 9) of public baths engineering was given in Chapter II., where it was remarked how the hot-water boiler system had of late years been abandoned for high pressure steam generation with calorifiers. An ordinary plan in modern swimming-bath is to arrange a quasi-injector and circulating pipes round the subway that naturally results from the exigencies of construction, under the bath gangway and dressing-boxes. For public baths work any kind of boiler suited to institutional engineering will be satisfactory, and water-tube and dry-backs well meet the duty, and demands, in restricted sites. The institutional swimming-bath—for schools, homes, etc.—will be a small affair if compared with important municipal examples, otherwise the details for heating and water-supply will correspond. It is a point in working convenience that such baths can be quickly filled and emptied, requiring ample diameter of pipes and drain. Some public baths have had more than one heating injector, but for the small institutional bath it suffices to have one such fitting at the deep end, throwing the water towards the shallow end, where the return circulating-pipe is connected. The rush of water out of this class of heating injector is very vigorous; it follows from this that part of the steam heat is converted into mechanical energy, the position being roughly as with the steam-engine where less than 10 per cent. of the heat is utilised in external work on the piston. To take the whole sum of sensible and latent heats as data for calculating steam required is plainly wrong, as this should suggest that the energy of movement of water came from nowhere.

Considerable coal is burned in heating, say, 100,000 gallons of water from 50° to 72° Fahr., so that if he could manage it the engineer would always advise the architect to so plan that the boilers may be near to the large swimming-baths. The site may not permit this in every case, but the object should be held in view. Unfortunately, many public baths are planned on purely architectural lines, without reference to, or knowledge of, steam-engineering first principles,

leading to a muddle and expense before matters are finally arranged. In large public baths and washhouses there is every reason for carefully weighing the advantages of auto-generation of electricity, for the exhaust steam may pass through the water-supply heaters, while the necessity for high-pressure steam boilers is in favour of generating current privately. The net heat required for slipper baths is represented by, say, forty gallons of water raised from 50° to 90° Fahr., and in large establishments a great number of such baths are "made" daily. Even if the slipper baths cannot take all exhaust steam into the calorifiers —that is, supposing, as in some districts, a large business in "swims" and relatively little call for ordinary baths—there is always a laundry and perhaps, public washhouse, able to utilise exhaust steam in heaters for drying chambers.

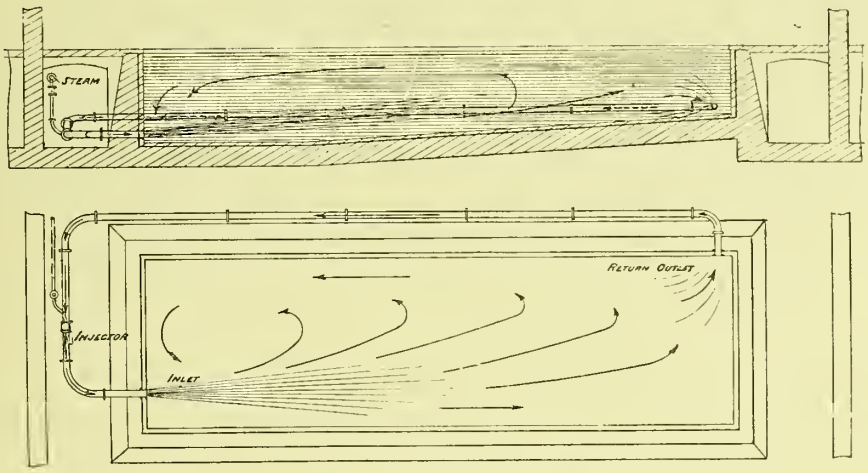


FIG. 54.—HEATING SWIMMING-BATH BY STEAM INJECTOR: DIAGRAM, PLAN AND SECTION, WITH APPROXIMATE STREAM LINES.

Fig. 54 is a diagram of arrangements for injector-heating of swimming-baths. Fig. 55 being an enlarged view of the injector. This latter may be made in various shapes ; as shown, it consists of a cast-iron body formed in rough general accordance with the injector principle. It has connections for water flow and return. One end of the casting is bored out to receive snugly a brass steam cone, machined almost to a knife-edge at its smaller end. A cover-plate secures this cone, and to this is bolted the flange of steam supply pipe. The whole device corresponds to, and forms a variety of, an apparatus commonly known as a "silent water-heater," and several steam-fitting firms manufacture cones or whole apparatus suited to swimming-bath work. An inspection of catalogues will save the engineer time, and render perhaps unnecessary, on most occasions, new design. Steam at pressure is supplied to the cone, and causes a

vigorous circulation of water, the temperature of which gradually rises. The system is simple, and may be confidently relied on as the best known method of swimming-bath heating; any elaborate devices offered to the engineer may be passed over as superfluous—not required.

Fig. 54 shows in more or less diagrammatic fashion the injector connected to circulating pipes, and the arrows give an approximate idea of stream-lines that result from putting the injector in action. The injection into the bath is very powerful, causing a vigorous circulation, which alone is beneficial, tending to prevent those patches of warmer and colder water so unpleasant to the bather. Exactly where the steam should enter the bath and water leave it may be a matter of opinion. As a rule the inflow is at the floor level of the deeper end of the bath, and the outflow at the shallow end, the circulating pipe running in the subway naturally formed under the bathers' gangways, as indicated on the drawing. The injector could be placed at any convenient point in the circulation pipes, but is no doubt preferably near to the inlet. It is reasonable to place the inlet at the deep end of the bath, if we consider that the injected water will rise, and, further, that the backwater in the bath, cooling, will tend towards the deep end and become heated by convection instead of passing through the injector. Room, however, exists for divergence of opinion, and from what was here last set out, it would seem quite reasonable to put both inlet and outlet at the deep end. Much should depend on the size and proportion of the bath. An exaggerated length, such as on the drawing, is, no doubt, best with the pipes arranged as shown. Many large baths have been fitted with several injectors, and multiple inlets and outlets, but the number of holes for pipes broken through swimming bath walls should be as few as possible, for which reason we find many filling, waste, and circulation pipes connected to one opening, the various requirements as to filling, emptying and heating being controlled by suitably-placed stop-valves. At the old Paddington Baths were four injectors with four return and four flow connections to the bath, besides a 12-inch waste connection—nine openings in all, in that which needs to be made a water-tight tank.

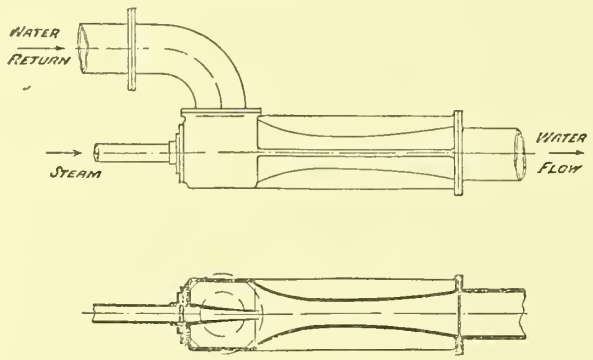


FIG. 55.—CAST IRON INJECTOR FOR HEATING SWIMMING-BATHS: INSERTED BRASS CONE AND FLANGE-PLATE COVER.

In a bath of 100,000 gallons, an average duty before the injector will be the

raising of 1,000,000 lb. water from, say, a main temperature of 50° to 70° as a minimum customary in swimming-baths. This may be called the maximum duty, and occurs each time the bath needs filling with fresh water, which in some establishments, in the height of the season, will be a daily occurrence. At other times the water is changed less frequently, and the duty consists merely of restoring each early morning the few units loss by radiation during the night. Assuming a hypothetical bath of 100,000 gallons requiring to be warmed 22°, we need to ascertain the boiler power necessary. As in all other matters, the work may be done either by a small or by a large boiler: in the latter case the time occupied will be shorter. A total of 1,000,000 × 22° is needed, or 22,000,000 units of heat. A round number frequently adopted and useful in tentative calculations is, available steam heat = 1,000; so that 22,000 lb. steam, on this basis, requires to be condensed to raise the water through 22° Fahr. of temperature. On the lines assumed, one boiler evaporating 22,000 lb. steam per hour would do the duty in one hour, and although an impracticable size for public bathhouse work, it is at once evident that powerful boilers are required. In business, the work must be accomplished in the time available between 10 p.m. and 7 a.m. after deducting time taken up in emptying—the heating may be commenced as soon as a fair body of water has entered the bath. An ordinary public bath-house boiler is a Lancashire, capable of evaporating about 6,000 lb. per hour, and such a boiler would, in theory, on the assumption made, do the work in 3 hours 40 minutes, raising the temperature 6° per hour. With coal of 14,000 B.T.U. and 75 per cent. thermal efficiency, 2,096 lb., or a little over 18 cwt. of fuel, would be required to be burned in the furnaces.

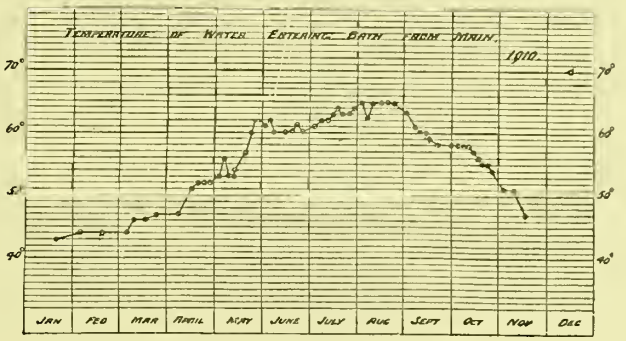


FIG. 56.—DIAGRAM SHOWING TEMPERATURES OF MAIN WATER ENTERING BATH.

The above is theory, but based on reasonable data. How far this agrees with practice in ordinary business, the author's note-books afford means of approximate comparison. In a metropolitan bath-house, in heating 100,000 gallons of water in a swimming-bath by means of an injector, 30 cwt. of coal were consumed in raising the water through 22° of temperature. For equal work accomplished our theoretical estimate is 18 cwt. against the 30 cwt. consumed in practice: nearly double the amount of coal is required in the latter instance.

Again, in another establishment, a similar duty of 1,000,000 lb. raised 22° required 27 cwt.—a somewhat improved performance; but it must be allowed that in the case where 30 cwt. fuel was required, a length of 300 feet of 5-inch steam main existed between the boiler and injector, which is necessarily greatly against efficiency in the boiler and injector as a combination.

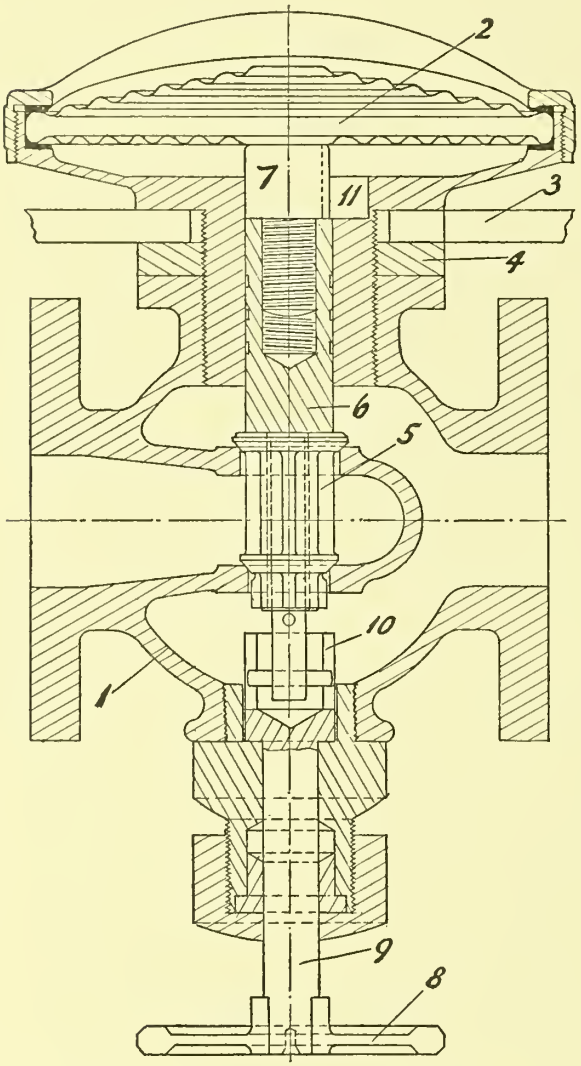


FIG. 57.—AUTOMATIC TEMPERATURE CONTROL VALVE FOR CALORIFIERS.

1, valve-box; 2, sensitive expansible chamber; 3, wall of calorifier; 4, lock-nut; 5, steam control valve; 6, piston; 7, adjustable plunger; 8, hand-wheel; 9, spindle; 10, fork; 11, feather.

In practical work, from a comparison of many results and from a broad consideration of the general conditions under which the engineering department of public baths is run, it would seem a safer plan (than steam evaporation) to base calculations on fuel required, and, following this plan, it will be found correct to estimate, instead of 75 per cent. efficiency, that about one-half the heat units in the coal are passed into the bath water. On this basis, about $1\frac{1}{4}$ cwt. of good steam coal raises the temperature of 100,000 gallons 1° Fahr. of temperature. This is a net result after allowing for unavoidable heat losses and radiation from the bath.

The conditions necessary to observe are good steam pressure—say 80 lb.—free passage of steam in, and short mains, and no throttling short of the small nozzle of the injector cone. This latter is not generally observed, and, in the illustration given, would not necessarily be brought about unless the small end of the cone were designed to let by the full output of steam from the boiler whilst the gauge showed the full pressure The fact is, these quasi-injectors should have tapered needle regulators in the cone, exactly on the genuine boiler-feeding injector principle, unless, indeed, the cone nozzle is carefully made to suit and to work under the

conditions above described. Throttling by an ordinary valve such as shown on the drawings (the usual practice) brings about a loss in water circulating energy, corresponding to that attending "wire-drawing."

From an old note-book is taken the following: "The bath superintendent remarked that, using a $1\frac{9}{16}$ inch bore injector cone, starting with a boiler pressure of 50 lb. per square inch, the pressure ran down to 10 lb. in boiler—i.e. the pressure could not be kept up; he therefore got the makers to supply another cone $1\frac{1}{4}$ inches diameter, and with this he could keep up the pressure to 50 lb." And a further note on this point runs, respecting bath heating at another establishment: "Stop-valve at injector $2\frac{1}{2}$ inches diameter, set about $\frac{1}{16}$ inch open to regulate injector; diameter of cone nozzle = $1\frac{1}{8}$ inch." Here, the defect of regulating by valve away from injector is exemplified. The steam was expanded, necessarily, between the valve and the nozzle, which is not in accordance with injector theory. The result is a loss of energy and less vigorous circulation of the water. Either the nozzle should be carefully adjusted to suit a certain boiler pressure, or the needle-valve control in the axial line of cone should be adopted.

The whole contrivance forms a combined pump and heater, and a very vigorous pump, the stream of water issuing into the bath being like that thrown from a small ship's propeller. It is known from this that great energy is put forth, and therefore at the most only the 966 units latent in steam in its fully expanded condition can be assumed to be available for heating. In theory, there is also the sensible heat of the water from 212° falling to a temperature midway between the lowest and highest temperatures concerned in the calculations, which, above, we have taken as 50° and 72°. It is also possible that some 1000 odd units of heat are actually imparted to water at the injector; but the various sources of loss suggest that considerations of coal required are more to the point than the question of injector efficiency.

Fig. 56 gives a useful curve of temperatures of main water entering bath, and has been prepared from data supplied by Mr. Sidney Poulson, the superintendent of the public baths in Lavington-street, S.E.

The importance of correct temperature in bath supply calorifiers has been urged. An ingenious device that may be relied on to prevent the evils from deposit arising from want of control of steam supply is shown in Fig. 57, representing the thermostatic valve of the Steam Fittings Company, Ltd. The appliance has many special features commending it to institutional engineers, foremost of which are that it does what is claimed—cuts off steam promptly at a margin of very few degrees of temperature, and also shows a direct saving in the annual fuel bill. When once adjusted the fitting requires no attention, may be applied in any position and to any calorifier installation, whether new or existing, and, whatever the pressure of steam, requires no reducing valve.

CHAPTER XIV.

THE INSTITUTION LAUNDRY.

The science of laundry planning for institutions comprises a knowledge of the routine in the particular institution, and a study of that which has been accomplished in efficiency of arrangement and machines in public and in commercial laundries generally.

A point requiring attention is the cycle of operations, to the end that the articles pass through apartments planned so that the several machines may be placed, and the attendants may work, conveniently. A first consideration in institutional laundries is a disinfecting chamber. The articles are passed through a drumlike apparatus and disinfected by heat. Another special feature strongly in evidence in hospitals and asylums and infirmaries is the arrangement for cleansing directly soiled articles, the so-called foul washhouse. Apart from these special additions, most modern laundries have a family resemblance. In some buildings—as, for example, small workhouses—it is considered an advantage to avoid machinery, the idea being to find steady occupation for some of the inmates. An example of non-mechanical laundry was shown in a diagrammatic plan—Fig. 17—of the Leytonstone pauper schools. This, which is not necessarily out of date, for a special duty, may stand for a distinct type of the hand-worked, small institutional laundry. It has attached an ironing room and coke-heated drying chamber, with two furnaces. In the washhouse are a number of troughs, each having water supply, together with steam nozzles for boiling. In addition are hand-operated rotary washing machines for suitable articles, and hand-operated centrifugal wringing machines. This comprises the elementary washhouse plant. The drying arrangement includes the practically standardised "horses" running on wheels, a device that, coupled with effective air-currents and a reasonable measure of heating, seems yet the most generally satisfactory, although various supposed improvements have been tried and suggested. In the ironing-room are a coke-heated stove, airing racks near to, and ironing boards liberally round the room, together with a hand-operated mangle.

If, now, we contrast the plan of a fully-equipped laundry for an institution of considerable size, we find that the whole plant is power-driven, and that more

elaborate machinery is installed. The idea is here efficiency, with economy and despatch—the lowest cost per 1000 articles, effectively cleaned in reasonable time. In this respect the institutional and the commercial laundries agree, and, as a result, also, the laundry for hospital, home, asylum, orphanage, and school, generally resemble one another, varying only in size and detail of equipment. There may, however, be this distinction, that in some institutions it is considered advisable to have separate laundries for inmates and for staff. In hospitals and infirmaries this is reasonable. In spite of contrary arguments, it seems difficult for the lay mind to entertain any other idea than that of reasonableness. It is advanced by the pan-laundryist that there is little chance of infection, and that the ordinary public do not know what washing goes on in the laundries that they patronise, and, further, that supervision is simplified where patients' and officers' laundries are combined. It seems scarcely in our way to debate the point; as before suggested, the authorities decide, and architect and engineer work to instructions. Where the dual system is adopted, a small part of the main laundry block is cut off for staff uses, with separate washing-machines, drying closet, and ironing room, connected, possibly, to the main laundry by a receiving lobby or room. All large laundries have both a receiving and a delivery room, a necessary provision for orderliness and dispatch. The modern tendency favours glass partitions as against glazed brick solid walls for divisions, and this must be considered an advance, enabling readier supervision, and making the place generally lighter and more cleanly in appearance.

The disinfecting arrangements comprise generally two chambers or rooms, through the party wall of which passes the iron drum. The two rooms are thus isolated, the only communication being through the disinfector. This has close-fitting doors either end. The apparatus should be planned close to the receiving-room of the laundry proper, while at the same time completely cut off. The foul washing place is not regarded as infectious, but offensive, and is generally planned off the main washhouse, and the articles go through a preliminary soaking, etc., to permit of their being passed through special washing machines with waste drainage direct to sewer. The thoroughness required here in plan, equipment and operation is self-evident.

Receiving-rooms and delivery-rooms are best grouped close together in order that the articles perform a circuit, returning to near where they entered the building, and possibly with doors on to a verandah or covered way, where they may arrive in bundles from the institution buildings. They both have a liberal amount of shelving.

The term "laundry" always, in the class of work under consideration, includes (1) the washhouse, and (2) the ironing-room. Into the former enters the

way from the receiving-room, and from the latter is the way into the delivery-room. All articles then go by a definite route, which is the fundamental idea. Somewhere on this route the clothes must be dried, and this position would diagrammatically be described as the angle of an L, the two arms representing the washhouse and the ironing-room ; although a square area, rather than an L, or an elongated parallelogram, best facilitates planning so as to bring the delivery and receiving rooms near together.

The equipment of such a laundry as above outlined comprises boiling troughs, washing troughs, rinsing and blue tanks, and power washing-machines and hydro extractors (wringers), and needs steam, hot and cold water pipes and shafting, and should have a powerful extraction ventilating fan as an effective appliance for clearing the atmosphere, together with ample louvre openings and plenty of windows and top-light, and so drained and channelled that a flood of water at any point would clear itself away at once.

The drying closet, formerly heated by coke stoves below, and with an extractor shaft above, is now largely steam-heated (live or exhaust), and a powerful forcing-fan blows air through the chamber into which the horses run. Abundance of air in currents is the secret of effective and rapid clothes-drying.

In the ironing-room more power appliances are fitted—ironing machines and mangles, and a coke-fired ironing-stove seems a necessity, for precisely the same basic reason for which coke is necessary in hot-air baths heating in place of steam heat. Such an ironing-room is completed by a generous provision of ironing tables.

The above is an outline of an average institutional laundry. Its size and precise machinery equipment must depend on the size and nature of the institution and the number of patients and officers, and the latter are often a large proportion of the total inmates of the building. The questions more particularly concerning the engineer as distinct from the architect are the power for laundry, its nature and amount, the power-conveying arrangements, steam and water supplies.

The best position for a laundry is undoubtedly near to the engineers' block. Both at Bethnal Green and at the Camberwell Infirmary the laundry is placed actually over the boiler-house, etc. ; and commonly, in country establishments, the laundry adjoins the engineers' department. In questions of power, and as this reacts on the question of heating, there is no occasion for concern as to heat losses in steam-pipes for the short lengths ruling under the conditions supposed. Live steam can be readily and economically transmitted for a laundry engine, and the generating sets being close by, so also can exhaust to subordinate heaters—radiators or coils. If, therefore, a steam-engine is chosen for laundry power purposes, matters shape harmoniously. But some question turns on the rival

systems — steam-engine or electric motor? Modern ideas have largely favoured electricity; but it does not necessarily follow that this is always the best recourse.

A considerable rule for institutional engineers is to introduce a prime mover between boiler and heaters whenever possible, to the end that the dynamic energy of steam at pressure may be utilised before passing on to heating duty. On the other hand, the convenience of cable transmission and readiness of switch control are points in favour of electricity, and indirectly also may lead to economy, just as it may inhere from the like convenience that electric lighting, although, perhaps, at times more expensive than gas, may result in superior final economy. The load represented by laundry machinery actuation is fairly regular on the long count. This is also so in detail as respects washing machines; but the centrifugal hydro-extractors require a considerable starting effort far in excess of the power needed for their continuous running, a position plainly shown in switchboard recording instruments. Under these general conditions, the electrical drive seems indicated, and present practice and tendency justified.

A suitable size of motor is assumed. In many cases the plan seems to have been to take the maximum possible load and a margin even; whereas, the machines alter-

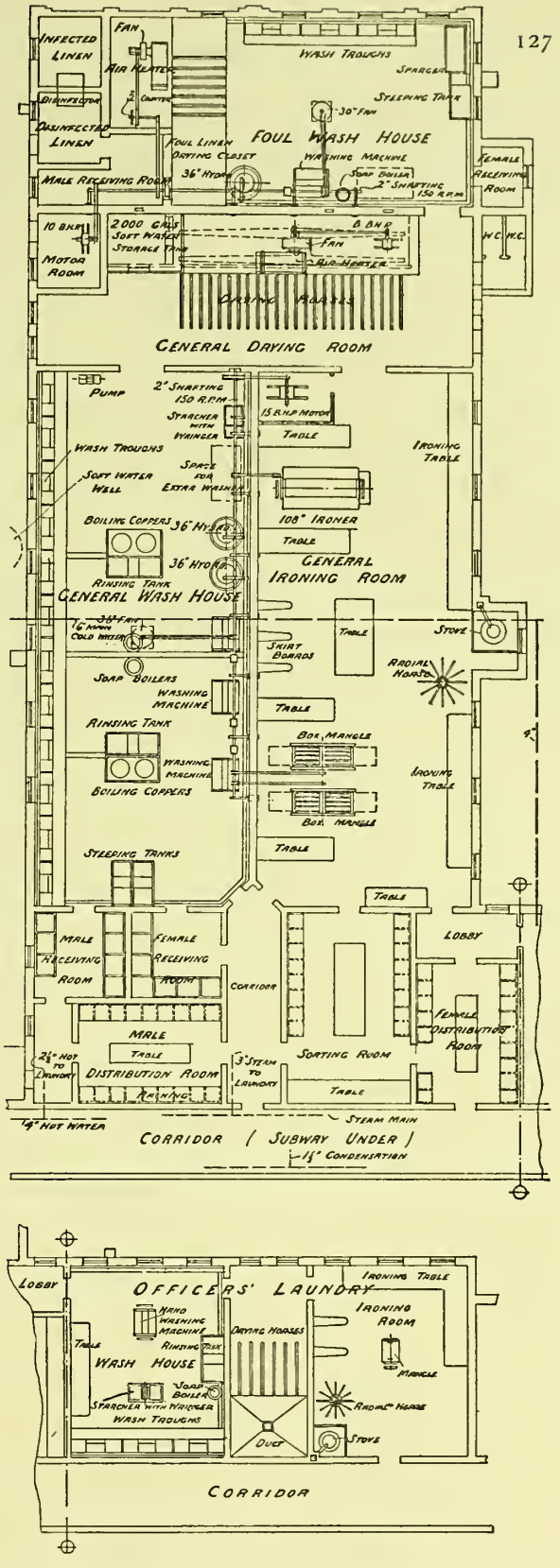


FIG. 58.—NETHERNE ASYLUM: PLAN OF LAUNDRY BLOCK.

nating from periods of rest to action, it is possible that a 50 per cent. load factor could be safely taken as basis of calculations, with saving in first cost of plant.

It has been found from practical tests that the utilisation of steam in place of coke for drying-chamber heating is convenient and economical; in one case the substitution of exhaust for coke-heating resulted in a saving of 12*s.* per week in coke, raised the temperature of the hot closets 20°, and rendered unnecessary the constant attention of an inmate of the institution about the furnaces.

The public laundry or washhouse, as provided under the Baths and Washhouses Acts, differs from the institutional.

The whole washing arrangements in such places comprise generally the establishment laundry (for towels, etc.), and the public washhouse, where, for a small charge, the public have access. The main idea after efficiency of the whole plan is that the washers shall enter and file out under the eye of the attendant in the pay office. There is generally no disinfecting chamber or provision for foul washing. Washing is by hand in troughs fitted with hot and cold water and steam nozzles. The drying-horse ends face sideways to the washers at their tubs, the object of this arrangement being that the washers may more readily keep an eye on their property in the drying chamber. Machinery is confined to centrifugal wringers; but the establishment laundry is fully equipped with labour-saving machinery. A definite route for washers, governed by their necessary operations, is a point to observe in the planning of the public washhouse. An ironing-room is added and planned en suite in accordance with the principle stated.

The power necessary for laundry may be estimated by scheduling the machines with the required horse-power as stated by makers, adding any allowance for fans, and assigning a suitable load-factor. In all these questions it is desirable first to consider the probability and possibility of extension in the future.

The steam required for laundries, like the steam required for kitchens, is a subject much needing careful experiment to arrive at reliable data. None such are extant. Mr. W. T. Hatch, M.Inst.C.E., the chief engineer to the Metropolitan Asylums Board, has, however, made public the following useful estimate of steam required for a hospital of 800 beds :—

	Lb. per Hour.
Electric light	2,000
Heating	10,000
Hot-water supplies	3,000
Laundry	2.500
Kitchen	1,100
	18,600

Fig. 58 shows the laundry at Netherne Asylum, planned by the architects, Messrs. G. T. Hine and Co., and fitted up by Messrs. W. Summerscales and Sons, of Keighley. The asylum accomodates about 1000 patients. The laundry is equipped with most modern plant, and represents an example of up-to-date laundry engineering for public institutions.

CHAPTER XV.

THE INSTITUTION KITCHEN.

The engineer retained for institutional work must for a time lay aside his slide-rule and enter heartily into certain prosaic matters concerning stewpans and other kitchen apparatus. In the large modern hotel, too, the culinary department, including elaborate refrigerating machinery, is a matter for serious study if the endeavours of the chef are to be facilitated by convenient planning and complete equipment, with up-to-date plant. Inasmuch as the kitchen in large hotels and institutions is in the hands of the charge-engineer, as respects maintenance of efficiency in the several appliances, it is to be assumed that it should come within the province of the consulting engineer to design. Frequently such results, although more strictly architect's business: but where the work of the architect ends and that of the engineer begins, and *vice versâ*, is somewhat difficult to define.

Considerable steam is taken by the large kitchen. In some institutions the amount may approach 20,000 lb. per day. It is not an easy matter to judge, and more accurate data are evidently required, and also that desideratum—a real steam meter. Anyhow, the fact that the amount may be heavy suggests (as with the laundry) close planning of the kitchen to the engineer's block. This does not always suit the general scheme of the building, and a long main is laid in the ordinary way down the pipe subways, which are a feature of modern institutions; and, in passing, it might be suggested that, instead of as so usual, making these ways just too small for upright walking, they should be a little larger. The main boilers commonly supply kitchen steam, hence, we cannot hold back the thought that there are occasions when a cleaner state of steam for cooking can be conceived. However, the practice rules; but in some cases independent boilers, special for kitchen use, are installed, sometimes as auxiliary only. The engineer has returned to his hot-well the condensation water from jackets, and from these only, since necessarily the emanation from what are called "wet-steam" ovens, etc., are impure. Such usually go to a drain by way of traps, often of special design to facilitate cleaning. The work of the steam fitter in kitchens will consist of taking along the main, providing a suitable reducing valve, with by-pass and throttle perhaps, and branches allocated to the positions

marked out on the plan for the several steam-heated appliances. A connection to the condensation main, with suitable branches to the steam traps, will be required. As a rule, all stop-cocks, regulators, and steam traps are supplied by the kitchen plant manufacturers, being included in quotations; so that the fitters' work is piping simply. Vapour pipes are required for emanations from pans, etc., and hot and cold water supplies. As the apparatus is self-contained in every way, as explained, if we include laying gas mains and branches, the engineer's work is one solely of pipes and branches and connections.

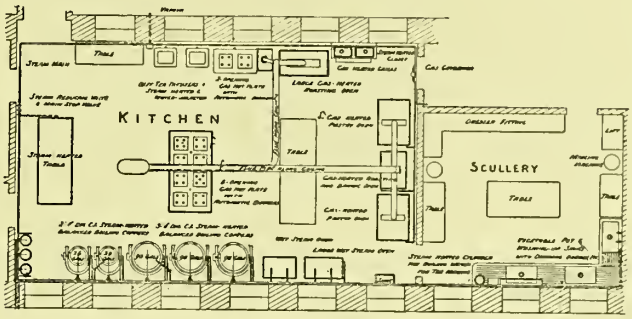


FIG. 59.—KITCHEN, ST. THOMAS'S HOSPITAL, LONDON: PLAN.

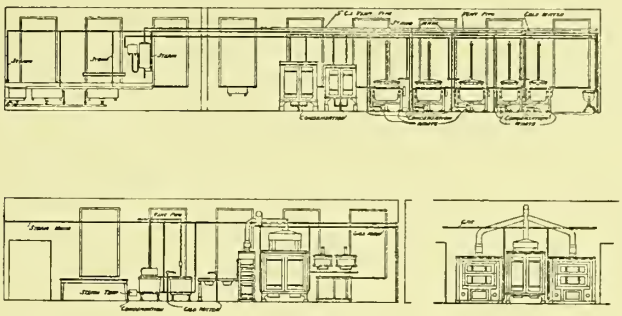


FIG. 60.—KITCHEN, ST. THOMAS'S HOSPITAL, LONDON: SECTIONS.

The metal walls of steam jackets are evidently neither more nor less than radiators, hence, it follows that where not lagged the kitchen may become, as it is in many hotels, a small inferno; more especially is this the case where there is one or more of the type of fitting called "central hot plates," and especially if these are coal or coke fired. In hotels such is a common practice; in hospitals the modern tendency is to exclude solid fuel, and rely upon gas. There are three points to observe in kitchen design and equipment: temperature of apartment as affected by the apparatus, ventilation for the sake of fresh air for the workers, and the matter of odours from the cooking. The first point is to be met by coatings and laggings, which, if complete, will avoid trouble. This especially refers to steam jacketed appliances. The second point is secured by large ducts and shafts and mechanical extraction by fans, and especially over gas appliances there should be large and roomy hoods connected to really efficient extractor shafts. The fan or fans and the hoods, thoroughly carried out, ensure a sweet kitchen, and one comfortable to the staff. The question of odour refers to that arising from wet-steam appliances. From plant of this nature the vapours emanating must be removed, and if just turned outside at a low level may be a cause of offence. To meet

this point requires care. The first essential is an extractor shaft, which has a constant up-draught without possibility of reversal, and carried up to the full height of the buildings. To such a main extractor, branches from the several vapour pipes may be safely connected.

The chef of to-day would not like to be deprived of steam plant. There are, however, many thing in the culinary way, best accomplished with other methods of heating; hence we find gas, coal (or coke), and steam appliances, in one and the same kitchen, the method of cooking found most suitable being adopted for each special work. Among modern steam appliances are ovens in a great variety of type; steam-jacketed pans, single or in batteries, steam-pan boilers, hot closets, and tables; plate warmers, kettles, tea infusers, and the like constituting an ordinary plant, with a few special appliances perhaps in hospital work.

An illustration is herewith given—Figs. 59 and 60—of a fine kitchen recently installed, under the supervision of Mr. Percivall Currey, F.R.I.B.A., by Messrs. James Slater Engineering, Limited, at St. Thomas's Hospital.

The whole space allotted is divided into scullery, or food preparation room, and kitchen proper, so that from the former—on the right of plan—the food passes on a definite route towards the left, through the kitchen processes, then to the steam-heated table, where it awaits the trollies to carry the dishes to the wards of the hospital. A certain orderliness in a kitchen results from this definite route.

The apparatus in the kitchen comprises a battery of steam-jacketed boiling pans, wet-steam ovens, and three small steam-jacketed pans for special food; a beef-tea infuser, and steam-heated closets and table. The remainder of the appliances are gas-heated—grills, roasting and baking ovens, and hot-plates, etc. The wet-steam ovens have vapour pipes connected to a main, running to the top of the building. The steam-jacketed pans have similar arrangements for ventilation, the jackets of all steam-heated appliances being connected to steam traps, and condensation carried back to the boiler-house, Mr. Currey's plans of which are given in Figs. 19, 20 and 21.

Wastes, as from boiling pans, are connected to drains. The arrangements for tea-making, as indicated on the section, permit a definite amount of fresh water to be boiled by a steam coil. Kitchens for hospitals on these first-class lines are found to cost from £2 to £2 5*s*. per patient.

The reader is referred to Fig. 17, for plans of the kitchen at the Bethnal Green Board of Guardians Schools, at Leytonstone.

CHAPTER XVI.

LIGHTING AND ELECTRICAL MACHINERY.

The sources of illumination open to the institutional engineer have of late been enlarged by the development of so-called petrol air-gas. For small country institutions this system merits careful consideration. Compressed gas is another recent innovation.

The sustained competitive invention in gas, and in the electrical science, makes it more difficult to decide on purely economic grounds between the rival systems. One feature in this question greatly affects the immediate issue : the readiness in "switching" on and off the electric current. It has been demonstrated in practice that this greatly encourages economy. So convenient is the ready and complete cut-out of the electric lamp that, excepting for quite special purposes, there seems no great call for any method of graduation. Those practically acquainted with institutional requirements lay considerable stress on the advantageous position that the switch-control gives to electricity.

Inasmuch as the installation of gas and its fittings hardly needs elucidation at the present date, and seeing that heating and power are components of any lighting problem where electricity is adopted, attention is here in the main confined to electrical matters. We have before ascertained that the convenience of using steam for heating naturally brings in steam and steam-actuated machinery, and, conversely, that the demand for power brings forward steam with its great out-balance of heat energy available for warming, but otherwise useless to the engineer.

Competent experts and authorities have laid down that it is, as a general rule, unwise to generate electricity where a supply at an economical price can be obtained from an outside source. What this exact price should be is a matter of some opinion, and no doubt must needs vary according to the value assignable to *pros* and to *cons*, that is to say, special circumstance may justify special recourse. Mr. W. T. Hatch, M.Inst.C.E., engineer-in-chief to the Metropolitan Asylums Board, gave evidence (C.D. 4503) that "in an institution using from 50,000 to 70,000 Board of Trade units per annum, one is probably not justified

in putting down generating plant if the supply can be obtained from an outside source at 2*d.* or less."

The question is necessarily somewhat involved and compound in effect, for reasons above stated, and also because the nature of institutions varies widely. Where we generally predicate a steam engine—on the grounds of exhaust available—quite special circumstances might make the small, high-speed, internal combustion engine best suited. Current may be obtainable at 2*d.* per unit, but our inquiries have indicated that, seeing how large ordinarily is the heating duty, auto-generation at a price in reality considerably over this may be not only excusable on general grounds, but actually show a business profit, or that which in commercial undertakings would be regarded as a gain. Hence, paradoxical as it may seem, electricity at 3*d.* per unit may be cheaper than at 2*d.* A large institution can undoubtedly—as a general rule, and assuming average conditions about such commual establishments—economise by auto-generation, although it requires to be remembered that the economy is at times indirect. The small institution plant (as compared with a large power-supply station) evidently cannot produce electrical energy at anything like the price of large steam power-houses, in which $\frac{1}{2}d.$ per unit is now obtainable. Practically what we find is that most large modern institutions *in the country* generate current. It might almost be said that in certain circumstances and conditions all do so; that not a few advantageously generate in London and large cities, there being a few anomalies, as hospitals, producing much steam at pressure purely for heating and at the same time paying large sums yearly to electrical companies. Stated in this way, the position suggests something irrational. Finally, as quite justifiably bearing on the question, there has been within the last year or so, on account, principally, of the more readily energised metallic filament, something of a "boom" in electrical lighting for country houses and the like. Putting the question broadly, one might say that, if it pays to generate for a country house, it must be at least as advantageous in a considerable institution. On the score of health and cleanliness, no doubt seems to exist at the present day but that electricity is far and away the best, much as the incandescent mantle has improved gas combustion. Some gas there must needs be in the large institution or hotel, for the modern kitchen almost of necessity has certain apparatus gas-heated, even where there are also steam and coke appliances.

On the broad issue, one would incline to the belief that, in most large institutions, generating electricity for lighting and for motors is a "paying" procedure, and the reason is that even a good engine does not utilise more than 10 per cent. of total steam energy, the bad far less, and the engine required for institution work—rarely exceeding fifty effective horse-power per engine unit, never

(or rarely) condensing, and frequently, if not generally, working at a low load-factor—comes out on these points as bad as any. And since not much more than 15 per cent. of exhaust heat can be taken in feed-heating, there is an available balance never under 75 per cent. of the utilisable potenial heat energy left in exhaust. Looked at in another way, the case becomes clearer: at one large institution of some 1,000 inmates, not much less than 18,000 lb. steam must be evaporated per hour, and is evaporated at high pressure, while all the time the authorities are paying great sums yearly for electrical energy. In this building are numbers of electric motors, paid for in the same way, while all the time quantities of live steam are passing to the numerous calorifiers, before reaching which the pressure is immensely reduced. Something not quite as it should be seems here indicated. The charge-engineer had in mind still further to reduce pressure at the calorifiers, so that the position will then be that steam will be generated at 80 lb., passed along lengthy mains, reduced to less than 25 lb. at calorifiers, the only practical part of the whole potential energy aroused that would be utilised being the steam for the boiler feed pumps. All other power is by motors paid for outside.

The indications for the moment are that institutions in the immediate future, if large, will be arranged for auto-generation of electricity, always in the country, and frequently in cities; smaller countryside buildings will mostly generate, and in the towns most generally take current from an outside source. In these latter—small country establishments—some development in petrol air-gas may take place.

The real, if unobstrusive, and possibly at times unobserved, controller of the position is building-heating. Arising from this, it is seen that large non-inhabited public buildings do not attempt to generate; and that the most suitable case for electricity is where night and day heating is required, as in hospitals and infirmaries and the like, and in asylums and homes.

It has before been advanced that the very imperfection of the steam-engine cycle renders this the best of prime movers. Were there not exhaust steam available, no doubt but that there could be a more general adoption of the internal combustion engine, the thermodynamic basis of which stands upon a higher plan of efficiency. In private lighting, the use of small petrol and petroleum engines has very greatly developed.

The question of heating should, indeed, first come under review by those concerned with a new lay-out of institutional engineering plant. If such decide upon steam, the position stands that, although atmospheric steam has sufficient, and, indeed, the most latent, heat, yet by the simple and inexpensive expedient of adding a little more heat to the generated low pressure steam, they may obtain energy for nothing, or, in the circumstances, so cheaply that it may be

said to cost nothing. The care and maintenance of generating plant must be a factor in the question; but does not affect the broader aspect, as above outlined, and the peculiarly advantageous position of steam and steam engine in public building engineering.

The following remarks by Mr. H. F. Parshall, M.Inst.C.E., in "Cassier's Magazine" for June, 1904, illuminate the point we have had under consideration: "It should be borne in mind that the only advantage which a power company has over an individual user is in the size of the undertaking, the increased economy of large generating sets, and an improved load factor owing to the diversity in the use of the power. Against this the power company has to bear the cost of transmission and conversion."

One penny a unit seems a reasonable total cost in large institutions. In a report by Dr. W. J. C. Keats, the medical superintendent of Camberwell Infirmary, under date April, 1905, the following useful one-day figures are given:—

Steam consumed by electric light engines . .	35,300 lb.
Board of Trade units generated . . .	597.
Cost of steam per Board of Trade unit . .	0.63 pence.
Maintenance, capital charges, wages, etc., per Board of Trade unit	0.33 pence.
Total cost of one unit of electricity . . .	0.96 pence.

Surmising a case settled where auto-generation of current appears advantageous, the engineer must concentrate his attention on the plant.

The Local Government Board Committee, instigated by Mr. John Burns, and reporting under date January 9, 1909 (C.D. 4,502), include the following remarks and schedule:—

"When the generation of electricity is undertaken, more care is needed in determining what plant should be installed than has been exercised in the past. In may instances the plant is excessive, as will be manifest from the following list of dynamos installed and the average maximum load at the institutions from which the Committee obtained returns:—

Institutions	Capacity in K.W. of each Dynamo installed	Total Capacity of Dynamos	Average Maximum Load in K.W.
A	60, 45, 10	115	17·5
B	37, 37, 37	111	26
C	75, 22, 9	106	30
D	30, 30, 20	80	15
E	37, 37,	74	16
F	28, 28,	6	15

Figs. 61 and 62 show the power plant at the Savoy Hotel, London. The lay-out was by Messrs. Kincaid, Waller, Manville, and Dawson, the consulting engineers. The plant comprises four large marine-type Babcock and Wilcox water-tube boilers, with chain-grate stokers, and Parsons' turbo-generators, all under the charge of Mr. Harold Hale, the company's chief engineer, The author is indebted to Mr. Reeve Smith, the managing director of the Savoy Hotel Limited, for permission to publish particulars of this important example of hotel engineering.

An average large modern institution is equipped with high-speed steam engines direct coupled to D.C. generators, multi-polar, shunt-wound, ordinarily for 100 volts. Less than this pressure, although reasonable in these days of metallic filament lamps, not according with requirements of motors. Moreover "copper" is saved, and in a large institution there is considerable cable-laying between the more or less isolated blocks.

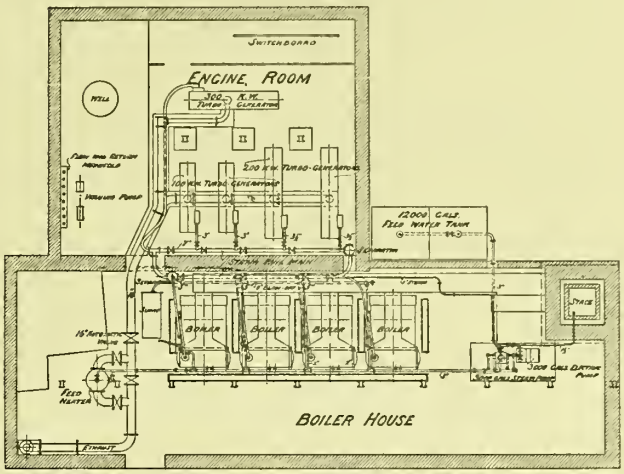


FIG. 61.—SAVOY HOTEL, LONDON: PLAN OF BOILER-HOUSE AND ENGINE-ROOM.

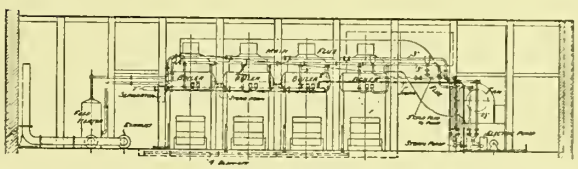


FIG. 62.—SAVOY HOTEL, LONDON: SECTION THROUGH BOILER-HOUSE.

The engines of to-day are enclosed compound with forced lubrication. Such machines may run long periods without attention. For the small size—50, or at the most 75 horse-power—needed in institutions, the turbine seems to require considerably more steam. It is likely that the lapse of time may remedy this position, when, a prime mover without oiled steam will be just what the charge-engineer of an institution would favour. Only quite special circumstances—excessive demand for power and convenient water—will suggest condensing.

The unit size of the institution prime mover must depend on the nature of the duty. One of the most ordinary arrangements is two large and one small engine; the first are interchangeable units, forming working machine and spare, usually; the latter for night load. The remark introduces the rather thorny subject of storage batteries. In its broadest aspect this question turns on whether

an engine is to be run night and day. In theory the storage battery is strongly indicated by conditions in public habitated institutions. It must be at once said that a tour of a number of such buildings will incline the inquirer to the belief that theory and practice do not here coincide; and it must be concluded that, as a general rule, accumulators do not find great favour with charge-engineers. Large numbers of such must have been installed and finally abandoned.

It illuminates this subject to consider in brief the work before the engineers. In institutions there are three watches, as indicated in Fig. 63, a copy from an actual record of a "Bristol" recording pressure gauge. The work has to go on this endless cycle system because, if nothing else were needed in a large part of the year, heating must continue during the night. A feature of the day is the laundry machine operation. As a rule, the laundry commences work at eight, and, with an hour's interval between twelve and one, runs on to 6 p.m. An institution having accumulators would run the engine (according to season) beyond six and, about general bed-time, shut down and switch over to the batteries. The alternative, and this appears a more pleasant recourse to those practically concerned in the engineering department, is to run an engine all night. Unless this engine is small it will, in the circumstances, be working at a most uneconomically low load; but all remarks concerning steam-engine efficiency may be well considered in parallel with what has been before said—that providing the whole steam required for building-heating does not exceed that required for power, no great concern need be felt as to the steam consumption of the engine as such. The point here brought forward and slurred over (as it were) may be offensive to the accurate-minded mechanical engineer; nevertheless, it results in practice that a clumsy engine, in reality fit for the scrap-heap, may nowadays be running in many a public building at a ridiculous load (for size), and yet no great harm occurring to anyone.

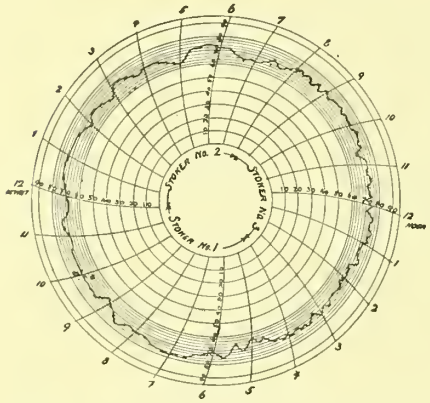


FIG. 63.—STEAM PRESSURE GAUGE RECORD.

Strictly speaking, the thread of argument is here incorrect, because there is an extra loss, but so small as to be of very little practical account. In laying out new plant, however, no engineer would carelessly put in any size engine, and excuse himself on the grounds advanced. Moreover, the special conditions supposed—excess of steam for heating—will not always rule. A prime con-

sideration for all engaged in equipping an institutional power-house will therefore be correct size of engine for duty.

To lay down plant of suitable capacity, several points must be observed. First, the nature of the building and what goes on there, and when. We are not here concerned with steam—that necessarily forms a separate matter, where there is either direct or indirect steam heating. The point is, how much *power* is required at maximum and minimum, the average load and the variation of the load and an average curve of variations. The maximum load will determine the size of the largest engine unit; and in a measure the lowest extended load (as at night) may suggest a size for the smaller engine.

Figs. 64, 65, 66, 67, 68, and 69 will be found interesting. They represent exact auto-records of an ammeter at the Bethnal Green Infirmary engine room under ordinary day-to-day conditions, actuating laundry machinery. The curves show the several conditions ruling in summer, autumn, spring, and winter; together with the small peaks from the starting of the laundry hydro-extractors, which are clearly

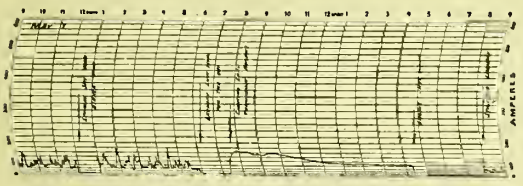


FIG. 64.—AMMETER RECORD, MAY 1.

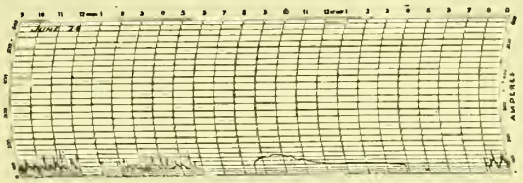


FIG. 65.—AMMETER RECORD, JUNE 24.

indicated, and demonstrate how great is the starting effort required by these machines, as compared with power necessary to maintain running. It is required of the engineer concerned with lay-out to construct for the proposed power-house a hypothetical curve on similar lines, or modified according to his knowledge of

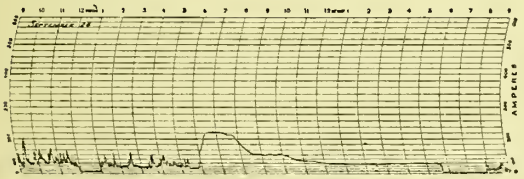


FIG. 66.—AMMETER RECORD, SEPTEMBER 24.

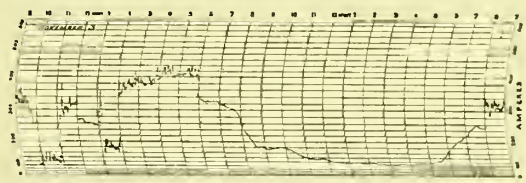


FIG. 67.—AMMETER RECORD, NOVEMBER 3.

the special conditions ruling or assumed to be likely to rule. The heaviest load in the curves are where upon the laundry load are superimposed heavy peaks resulting from fog; and it should be remembered in large towns how the same peaks may suddenly appear even on a summer's day, compelling the charge-engineer to be on the look-out. Fortunately there is such a great disproportion

between the boilers of an ordinary large public institution and the engines, that there is always ample margin of steam available on a slight opening-up by stokers; so that, providing the engines at work are capable of meeting the sudden load, there is always plenty of steam. The position here is therefore far less involved than in the public supply station, where not only engines may be added but also boilers. It is quite practical to make accumulators assist on these occasions, for the small work under consideration, and take up part of the duty on abnormal peaks, but the system seems to have been very little adopted in practice, ideal as it seems in theory.

It will be seen from an inspection of the curves, and hardly needs pointing out, that the winter load in a public institution far outweighs the summer. Except for a few odd lights in dark places, the summer day's work is laundry only; but this does not take into account water-pumping, lift actuation, or ventilating fans, the latter naturally coming in the summer to balance work as contrasted with the winter. The consideration suggests that there may be buildings where may rule

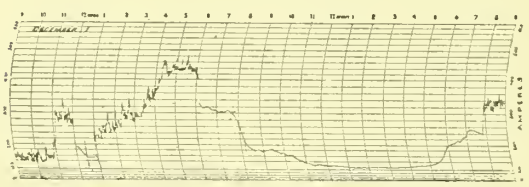


FIG. 68.—AMMETER RECORD, DECEMBER 1.

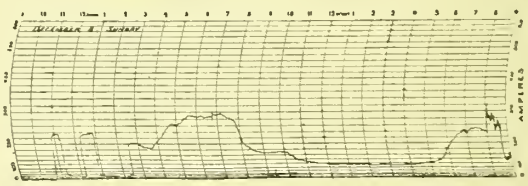


FIG. 69.—AMMETER RECORD, DECEMBER 8 (SUNDAY).

conditions divisible into three grades—a full, intermediate, and low load, each sustained at times for a considerable number of hours. Under such circumstances, it seems reasonable to provide three engine units of correspondingly graduated power, but in practice this is not a usual recourse. The danger is too great a refinement of idea, leading to an error always more formidable than too much power—provision below requirements. It is for this reason wise to err on the side of providing some excess. The curves given show that it would be impossible to adjust the engine power at economical load to suit every variation. The most that can be done is to make a happy and judicious selection, after careful estimate and study of conditions. The curves illustrated suggest, in places, condensing; and if there were no demand for exhaust steam, and the total load were large, would need condensing if one engine was expected to cope with all variations with reasonable economy. It will be interesting to note that the power plant at Bethnal Green Infirmary consists of two 90 i.h.p. engines and one of 45 i.h.p. The general arrangement of the engineering department at Bethnal Green is

given in Fig. 29. Fig. 70 will also be of interest to the reader, as giving an idea of coal consumption and its variation at this infirmary.

The cables in large institutions are ordinarily conducted from block to block in subways. All modern buildings of this class are arranged with these underground passages, more or less thoroughly planned. The present-day institution is not one building in the sense, for instance, that a town hall is one building, but is split up into a number of units which need to be connected by cables and pipes. At first sight only the hospital seems to need this separation into distinct units, but in practice the system generally prevails. In some varieties of municipal or parochial communal establishments the separate buildings are so disposed that the whole appears like a small town of detached houses. The economic result of this fashion is necessarily increased cost in piping and cables, and to save copper in conductors the three-wire system is at times a good and practical recourse, only, however, between blocks and up to, and as far only as, the main distribution boards of these blocks; at the same time it has been authoritatively suggested that, in asylums, the three-wire system *in* the blocks has a certain advantage, rendering absolute failure of light less possible. Seeing how large is the area covered by large modern institutions, and how widely distributed and how numerous are the unit blocks comprising the whole establishment, a system of cable laying that may save 50 per cent. of copper is worthy of careful consideration. Whatever the method of cable-laying, it should be seen that the leads are get-at-able, and all neatly pre-arranged on plan. Whilst subways are building, for any purpose of this kind, it always seems sensible to make them so that at least the average-height man can walk upright, and what is perhaps more to the purpose, work at repairs, etc., effectively. Were it only a matter of cables no doubt the ordinary solid or conduit system would be adopted; but the whole array of cables, steam condensation, and hot and cold water pipes, besides possibly special fire service mains, make such a formidable total that the well-planned, full-sized subway of waterproof walls and concrete or arched roof, sufficiently roomy for workers to work, seems more to the purpose, and in the end no doubt conducive to economy.

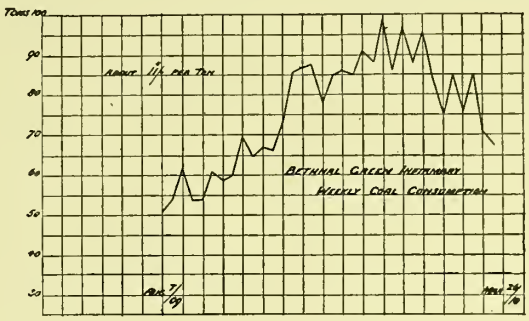


FIG. 70.—BETHNAL GREEN INFIRMARY: WEEKLY COAL CONSUMPTION.

The half-hearted system comprises undersized subways wherein one must more or less crawl. On a thorough system of separate block institution building

on a large scale, one should be able to walk comfortably from all parts to the engineer's block, and that without getting entangled in cables and pipes, or tripping up over obstacles. Modern practice tends towards these complete measures, a marked feature in water engineering and in cable-laying of to-day being a decent respect for a pipe or a cable as something worth placing accurately on a plan, neatly finished or labelled for easy identification, and perhaps coloured specifically, to this end, as in the thorough piece of work of this nature in the new General Post Office.

Where electrical energy is purchased from outside, a small sub-station may be required as in the example given in Figs. 71 and 72, diagrams of the new sub-station at St. Thomas's Hospital, from plans supplied by Mr. Percivall Currey, the architect to the hospital, and from information as to the electrical machinery and installation from Mr. A. Grove, the electrical consulting engineer who arranged the plant. Two supply companys' mains are here tapped, the high tension alternating current passing through step-down transformers and being converted to a suitable voltage for lighting and motors in the institution. For operating the push-button lifts, a D.C. supply is required, and this is accomplished by means of motor-generators, the energy passing *viâ* accumulators.

Mr. Currey's plans and Mr. Grove's lay-out have provided two high-tension transformer chambers, a motor-generator room and battery room, with 53 cells of 620 ampere hour capacity, mounted on teak bearers on brick piers. The distribution leads pass to the low-tension A.C. switchboard; iron pipes carry the cables to the A.C. motors, and similar pipes carry the cables from the D.C. generators to the D.C. switchboard all as generally indicated on the drawing, the other cables being neatly arranged in commodious checker-plate covered channels, a channel being arranged across the battery room. The whole presents a compact example of institutional sub-station with converting apparatus. The motor-generators are mounted on what are practically four coach-springs, preventing propagation of vibration. This sub-station has been most compactly arranged between Westminster Bridge wing-wall and the first hospital pavilion. In St. Thomas's Hospital are some 50 odd motors from $\frac{1}{2}$ h.p. upwards and there are five push-button lifts. The motor-generators are operated three times a week and the lift motors take current from the batteries.

Reverting to the question of secondary electrical machinery required in hospitals and the like public institutions—generators being here considered primary machines — three-wire installations will need balancers and, where batteries are used, boosters. Balancing machines and boosters are accessory power-house plant; it is the duty before the motors, which—together with the total of lamps—need careful review in estimating for generating plant and engines.

The total of these is not difficult to schedule beforehand, so that some of the extravagant generating arrangements at times laid down do not seem justified—

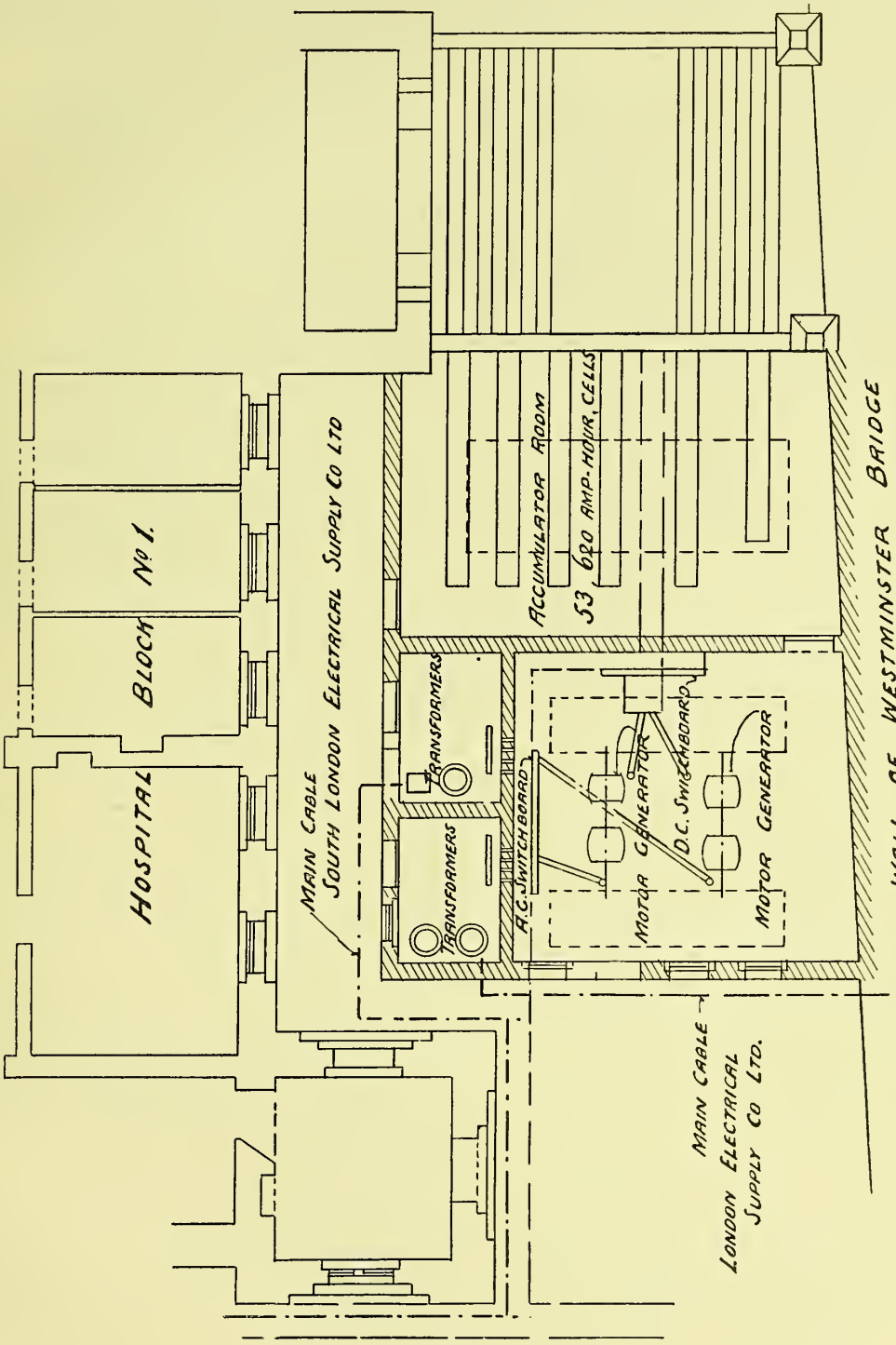


FIG. 71.—PLAN OF SUB-STATION, ST. THOMAS'S HOSPITAL, LONDON.

as a ratio of 100 h.p. in engines to 15 h.p. of maximum average load. It has been pointed out that certain considerations respecting the utilisation of exhaust for heating make less objectionable an outsize of engine; but it requires to be remembered that the extra size machine brings in an extra size of account for settlement.

If there be no excuse for absurdly over-engined institutional power-stations, there is, however, every reason for caution not to under-estimate for power-plant lay-out. With a 50 h.p. day engine and a 10 h.p. night load engine, a spare 50 h.p. will be required. Add the spare and we get 110 h.p. for 50 h.p. maximum and this, as things are generally arranged, must be considered satisfactory. Had there been no night work the small engine would have been unnecessary, leaving a maximum demand met with 50 h.p. and similar power as spare. It must be understood that in this case a real full-size spare, and power of spare equal that

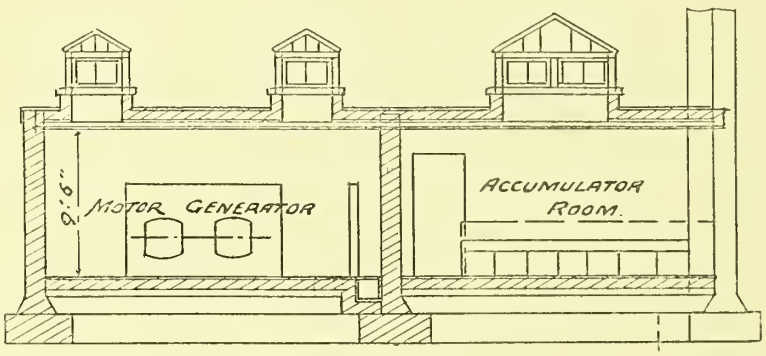


FIG. 72.—SECTION OF SUB-STATION, ST. THOMAS'S HOSPITAL, LONDON.

of working machine, is a necessary arrangement. Three equal-sized engines are often laid down. On the general considerations hereinbefore discussed this does not seem quite the thing, and for night running would not be a very scientific arrangement; and it would be difficult to call to mind any type of habitated institutional building suiting this arrangement. Add, however, a battery for night duty and the arrangement of three equal units becomes as excellent for engines and generators as it so frequently proves for boilers. In this case the plan must be considered one of the most workmanlike, and is based on the science of probabilities—that it is unlikely that two of the units will break down at the same time. In theory there is a defect—that if power equal to the whole maximum demand fail, there is only 50 per cent. spare in reserve; in practice the system works well, and at times one might even conceive of an arrangement where the third engine came in on abnormal peaks that caused a demand over and above

that capable of being met by two units working temporarily above their most economical load, or at what is termed the maximum continuous load. With the reliable modern high-speed steam engine the idea seems reasonable enough. It should be understood that the arrangement here in view is that *two* engines cope with the maximum average.

The great aim in a commercial power-station is to maintain machines running as nearly as may be at their most economical load, which some makers rate at three-fourths of the maximum continuous output for small engines and a considerably less margin in large ones. In the modern institution engine-room, and where exhaust goes to heating, the point is not of great importance, perhaps, but all the difference may be made between 25 lb. steam per i.h.p. per hour for high class engines, and more like 40 lb. where the load constantly and widely varies, from nothing to maximum at which the engine will keep at the work. In the public supply station an array of units of widely different power, all steam-heated against a sudden call, is the recourse. In the institutional engine-room either a small or large engine may be at work according to the season of the year, and it continues to meet all variation within its capabilities. Regarding the engine, as virtually a by-pass on the route of the steam to building heating, it is seen that the matter is one of prime cost, rather than of steam economy, and this is the more apparent if it be remembered that steam condensed behind pistons for the most part re-evaporates on expansion. And although such re-evaporation does not improve the steam-engine cycle, but indeed constitutes a real deformation, on evaporation the temporarily condensed steam is carried over to heaters with heat, as such, practically unimpaired. If, neglecting these facts that apparently justify somewhat loose and cavalierly treatment of institutional power-plant, we regard the position with the keen eye for economy of the public electrical supply-station engineer, it is plain from the elementary considerations we have made, that until the whole general character and the especial features of a load are known, or cautiously assumed from the best available data, no really intelligent estimate can be made of the most suitable method of splitting up the units of power. The necessary procedure therefore entails a complete and detailed schedule of lights and motors, together with a curve even if hypothetical, that will show the time elements—position and duration of peaks, etc. It must be considered that it is in the load-factor question where experience will tell, and that the excessively overpowered engine-rooms have probably arisen from ignoring the load-factor and providing for complete maximum, which starts off by assuming that all the laundry motors, lift motors, and ventilating motors are to work at top speed at once and together. A careful review of the nature of duties, their time and duration in the day-cycle and whole-hearted inquiry among similar types

and size of institution, while preventing under-estimating, will be all points influencing a decision in the problem it is required to determine—number and actual relative power of units. This method of procedure awakens the interest of the mechanical engineer, to whom the chance laying down of approximate plant is, or should be, offensive.

It is a point that greatly exercises the thoughts of the experienced power-station designer—and necessarily so; for, if there be any formulæ that can be brought to his assistance the author must confess his complete ignorance of such.

Fig. 73 is a drawing of foundations for one of Messrs. Davey, Paxman and Co.'s enclosed compound high speed engines for direct coupling to dynamo, of a size useful in institutional engineering. The machine stands on 4 feet of concrete and is held down by $\frac{7}{8}$-inch bolts, finally grouted in, representing ordinary practice in fixing small engines for electric lighting. Properly carried out, the whole foundation sets in a solid mass, and need be in no wise inferior to apparently better and more elaborate methods.

The drawing shows an exhaust-pipe trench, a point that will attract the attention of the institutional engineer. It is by no means always necessary to have a low level exhaust main, if convenience should suggest some overhead device; but it is more natural, considering steam phenomena, to follow the ordinary practice, in which case the pipe trench will run into the calorifier chamber, and, for neat work, be covered with chequer plates.

A good modern small high-speed steam engine should require about 35 lb. steam per K.W. hour, when averaging from say one-half to full, maximum economy, load. Such a figure is at any rate a reasonable basis for calculating amount of heat rejected in exhaust during the working of a high class modern engine; and taking Figs. 64 to 69 it is seen how the demand arises in most institutions for a live steam supply to supplement exhaust. The constant variation in amount of steam passing through engines renders a connection between boilers and calorifiers a necessity under most running conditions. On page 128 is an estimate for steam required for a hospital of 800 beds, where the electric light engines were only debited with 2000 lb. as against 10,000 for the heating duty; and indeed it is worth noting that the steam required for building heating is much over one-half the whole necessary supply. The figures referred to provoke thought. The whole steam is 18,000 lb. per hour; for the electric light engines only 2000 lb. It is evident that in such cases very little, relatively, of the whole steam raised can have its dynamic energy usefully employed. In the instance given it is less than one-ninth, and that is an estimation in gross, i.e. not allowing for heat lost in the engines. The practical question here seems to suggest itself, and bears greatly on the problem of inside or outside electric lighting for

institutions:—If only one-ninth can be used dynamically, is it worth while to raise the whole steam at high pressure?

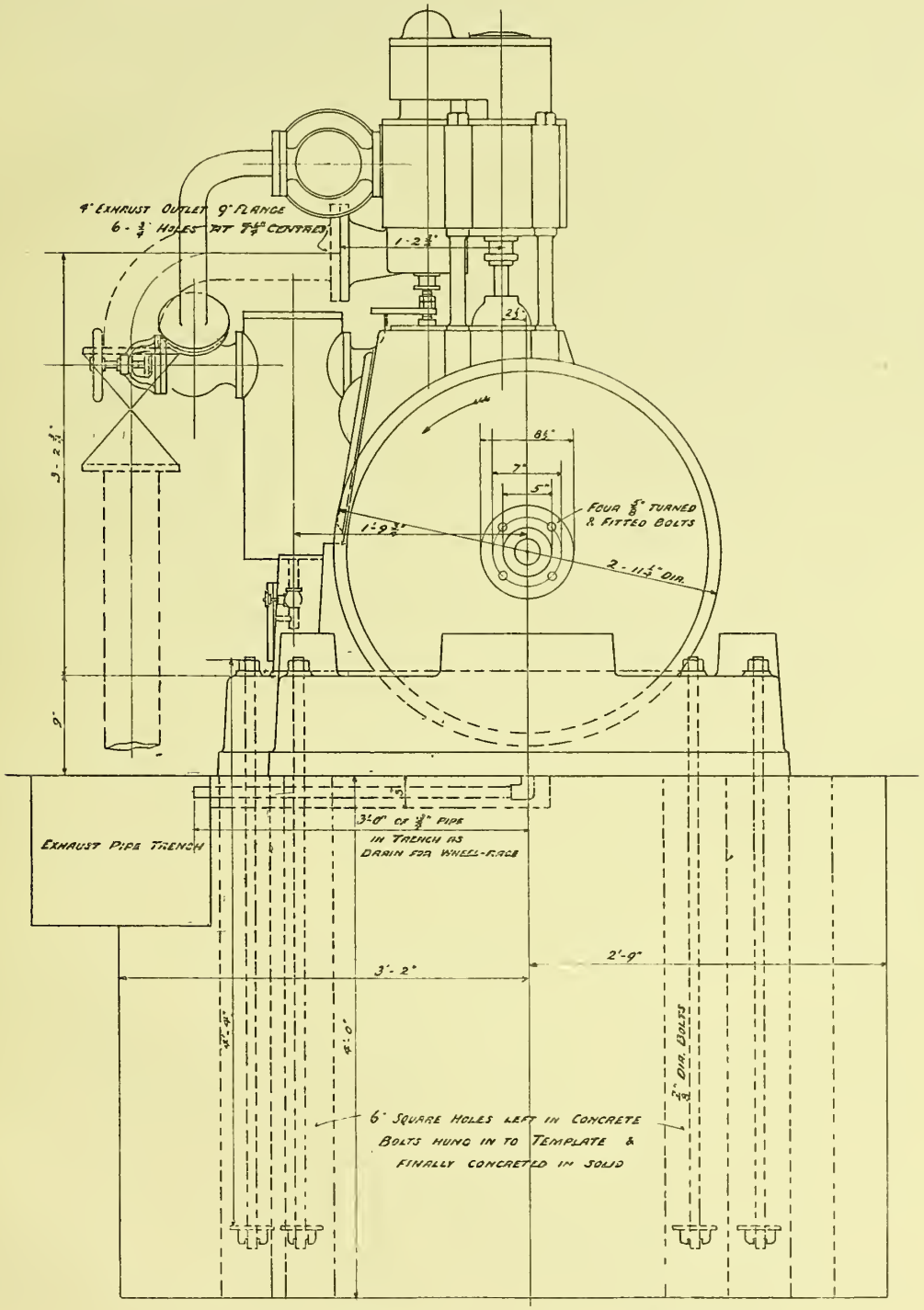


FIG. 73.—FOUNDATIONS FOR HIGH-SPEED STEAM ENGINE.

The answer, it would seem, can only be given after considering the nature of the institution, the principle of heating, whether high pressure steam is needed on this principle, and whether, as a final conclusion, if no steam is raised, capital costs can be so reduced that it figures out more economical to purchase electrical energy from outside.

The type of electrical generating machinery bearing greatest resemblance to that in institutional engine rooms is to be found in the small provincial power station. Not many such are on so small a scale, but examples can be found among those employing the steam engine as prime mover. In such places we find machinery and apparatus of sufficiently modest extent not to demand a great deal of attention in running. The study of arrangements made and conditions under which such power-houses are operated is likely to indicate the best recourse for institutional engineers; for these establishments are promoted to produce a commercial profit. Such concerns should therefore show us how to best run small electrical generating plant with the greatest economy. The character of the business done is comparable to that in the institution—so much light and power in the daytime, an evening peak and a small night-load. The power house engineer, however, cannot utilise more exhaust steam than that required for feed-water heating.

In the course of the Local Government Board inquiry before referred to, Mr. J. C. Wigham, chief engineer of Edmundson's Electricity Corporation, was examined, and in his evidence, alluded to the power station at Cromer as being one of the smallest supply undertakings run by his company. The author asked Messrs. Edmundson's Electricity Corporation for a plan of a small battery-equipped power-house that would be interesting to institutional engineers. Messrs. Edmundson's forwarded a plan which proved to be that of Cromer, and from this the accompanying drawing, Fig. 74, was prepared. The total generating capacity is only 180 K.W., so that, the installed engine power is comparable to that required in many public institutions.

It will be seen that the engines and boilers are compactly planned in a plain rectangular space, with the accepted modern power-house arrangement of temporary end walls, permitting new boiler or engine units being laid down economically, i.e., without pulling down expensive solid walls. One Babcock and Wilcox boiler of 1827 square feet, and two Sugden boilers of 1218 square feet heating surface are installed.

The generating plant consists of two 90 K.W. sets of Belliss and Morcom engines with four-pole Parker dynamos. The distribution is on the three-wire system, sets of balancer-boosters being arranged against the engine-room wall.

One battery room is disposed as shown on the plan. On a floor above are a further 130 cells. The system of working at Cromer is that the engines run from sunset to 11.30 p.m., all the rest of the time is taken by the accumulators.

On an average this avoids running the sets for 18 hours a day. The system may require starting up an hour and a half earlier in winter to charge the accumulators.

The object of a company running a power-station is the profitable sale of electrical current An object before the institutional engineer is economy in the use of coal. The question before those arranging plant for the latter is, whether or no the installation of a battery will tend to economy in working. It would seem that, as in so many other things, no definite answer can be given until the conditions ruling, or likely to rule, in the installation are clearly ascertained. Much seems to hinge upon whether steam at pressure is to be kept in boilers during the night, for it is well understood in these days when high speed steam engines run long hours without attention, that one man who may be nominally only a stoker, can quite well attend to furnaces, water and steam gauges and a simple electrical generating set. Supposing, however, that running the engines involves special attendance at night time, it is considered that under these circumstances a battery is an undoubted advantage. Taking these as premises, it will, without doubt, be found that the apparent dislike of charge-engineers for batteries, and their apparent neglect of these appliances arises, not from wilfulness but because the engineer, as the man on

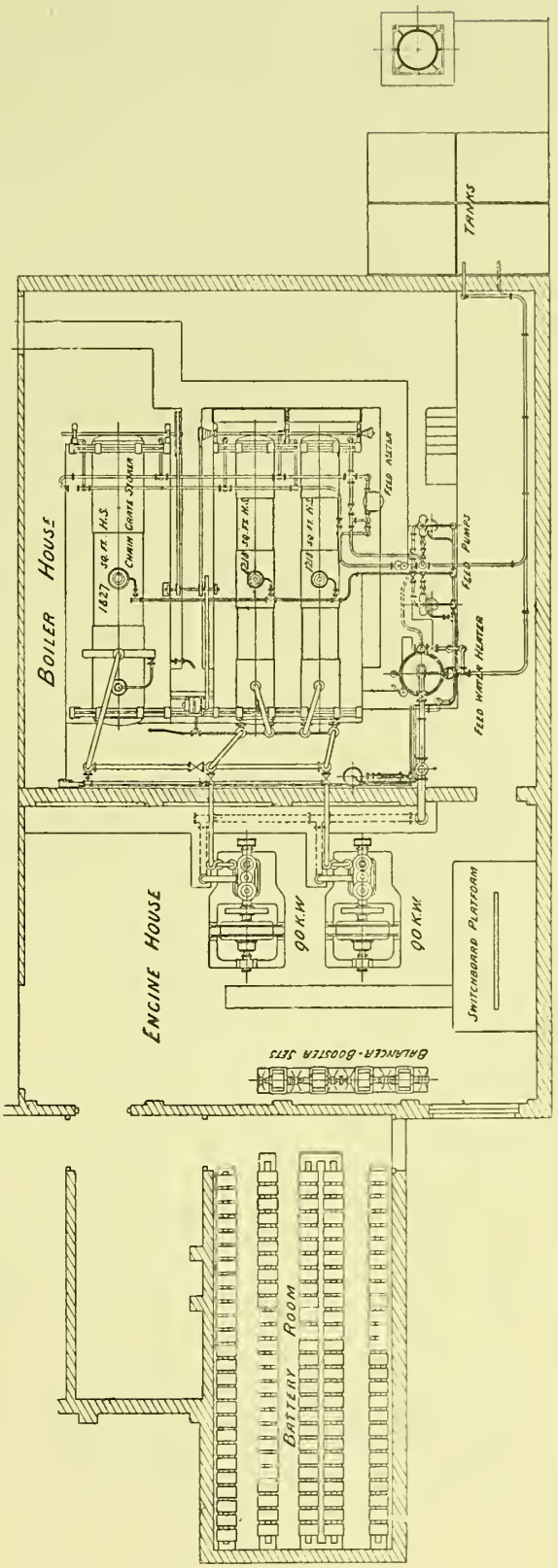


FIG. 74.—POWER-HOUSE, CROMER.

the spot who gets a grasp of things, finds that, under the arrangements ruling at his establishment, the battery is superfluous—not required on either grounds of economy or convenience. If this assumption is correct, the somewhat debated question of accumulators for institutional engineers may take a clearer aspect. If there are boilers under steam at pressure at night, and a stoker in attendance, continue to run the engines; if there is no steam and no night stoker, obviously there must be either no light or else an efficient secondary battery duly charged during the day. This seems to fine down considerably, a point that is apt to take on a hazy and involved appearance.

It requires to be noted that batteries are relatively inexpensive appliances, of very reasonably good life if properly attended, and not requiring much time per week if regularly attended. It results that accumulators may save in capital expenditure, principally on a system of working whereby they take up the top of a peak, as it may be put. There are thus, three chief ways in which the accumulator may be usefully applied:—

(A) Assist on the peak, or on excess loads generally.

(B) Take the night load.

(C) Take the day load.

Fig. 75, is a diagram of battery connections prepared by the Electrical Power Storage Company Ltd.

In connection with the above review of main circumstances and conditions, it is a significant reflection that great numbers of public institutions do necessarily keep boilers under normal steam pressure, and have necessarily a night stoker regularly in attendance, all a result of either direct or indirect steam building heating. One is, therefore, forced, generally to conclude that if batteries are installed in institutions it should be for taking the night load, and conditions suited to this system do not rule in all—if indeed in many—public buildings of this nature.

The ever-present laundry, and the lifts, fans etc., operating in most large institutions, seem to preclude the idea of batteries for day load, especially when the contingency of fog is remembered.

Either for night load as preferable, or to assist at peaks in some cases, seems the principle to follow with the institutional secondary battery, and possibly in certain events where extra power plant cannot conveniently be added, the nature of that already installed may suggest accumulators as a useful recourse.

The field comprised in the term "institutional engineering" is so wide that the most extended review thereon must result in a mere outline sketch. This cannot well be otherwise, and as a consequence little has been said herein as to plant and machinery in detail. The object has been to endeavour to concentrate

attention on lay-out. This is the first concern of the consulting engineer—to obtain a broad grasp of whole problems as distinct from mere detail consideration of machines and their working.

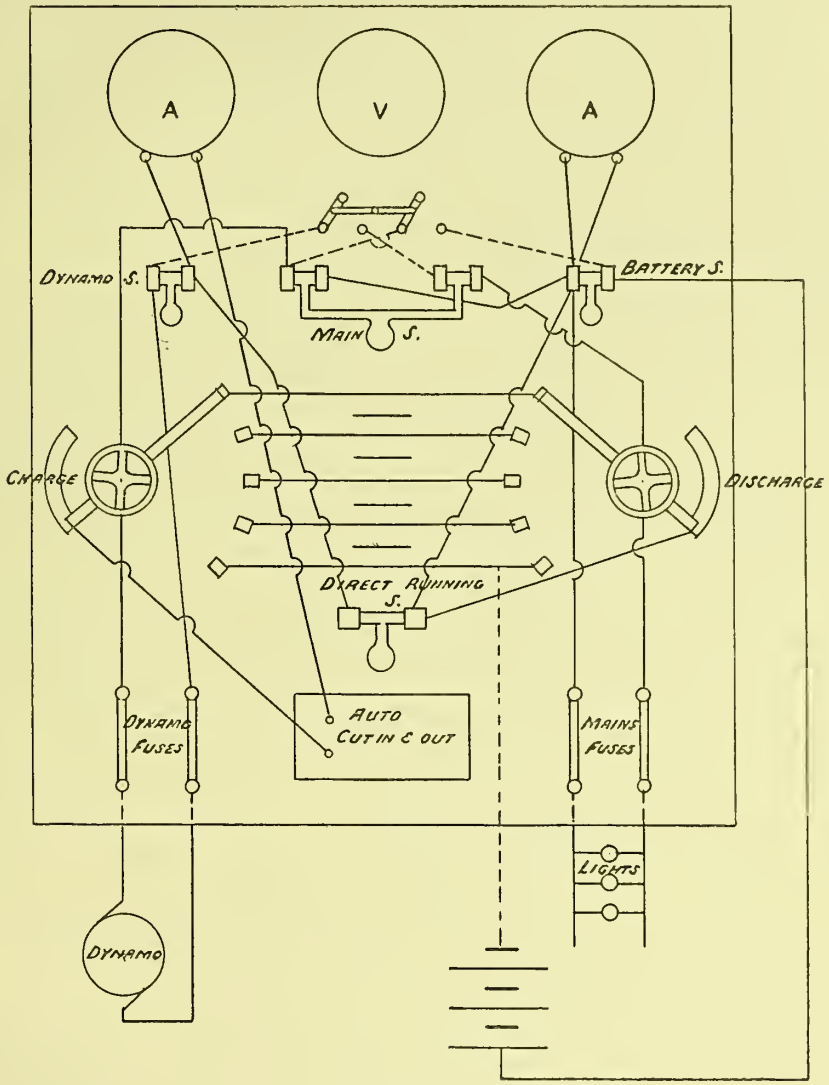


FIG. 75.—BATTERY CONNECTIONS.

(1) Direct running from dynamo to load; (2) Dynamo and battery in parallel on load; (3) Dynamo shut down and battery alone taking load.

The whole engineering equipment needs to be regarded as one machine, and reviewed from a standpoint sufficiently remote to obliterate obtrusive detail. A complete institutional engineering plant rightly forms one piece of mechanism, all parts subordinated to a common object. The whole plant, if say, assembled

in an open field, could be temporarily connected up in all its parts. It would then be seen to constitute a self-contained machine, for giving heat, light and power, etc., originating in coal combustion, the efficiency of which would be a measure of fuel burned per unit of objects satisfactorily attained. Given complete efficiency—such as satisfies the governor or supervisor of the building and the authorities to whom he is responsible, the success of the engineer may be expressed in terms of coal saved in the yearly fuel bill. As these bills may be the sum of amounts totalling a hundred tons or so per week, the potential economy in public money is seen to be great, if the badly-working institution plant were brought into line with those where a commendably high plane of efficiency has been attained.

Taking this one-machine view of the institutional engineering plant, the thermal efficiency of even a poor example, necessarily stands high. In an ordinary works a non-condensing steam engine operating the works machinery may use, say ten per cent. of the heat units in the coal. High pressure, expansion and condensing may improve the engine efficiency, but there is always the vast waste to the condenser. Here the institutional engineer economises—he uses this heat for warming buildings. It is this method, of operating his whole plant, that leads to a whole economy unattainable by the power engineer. Where in the one case the balance of heat units are dissipated to atmosphere, in the other they go to make comfortable the inhabitants of a building. It is to be noted that the gain here is real and proportionate, and is represented—approximately—by 966 units of heat to the total of sensible and latent heat per pound of steam passing the engine stop-valve. Where heat rolls away in clouds above cooling-towers the institutional engineer utilises this profitably and to the full. He burns one ton of coal in the boiler furnaces ; only two hundred-weight or so may take useful effect on pistons ; but, whereas at the power station the eighteen hundred-weights per ton go to atmosphere, the great balance of heat units, or a very considerable proportion of such reappear usefully at the institution radiators.

It has b en herein suggested that the problems before the engineer concerned with the lay-out of plant for public institutions are essentially thermodynamic. It must be concluded that they are pre-eminently so, and that they afford scope for a whole thermal efficiency unequalled in any installation of machines concerned with the utilisation of heat energy derived from the combustion of coal.

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